21016

National Library
of Canada

Bibliothèque nationale
du Canada

**CANADIAN THESES
ON MICROFICHE**

***THÈSES CANADIENNES
SUR MICROFICHE***

NAME OF AUTHOR/*NOM DE L'AUTEUR* H Arthur Quinney

TITLE OF THESIS/*TITRE DE LA THÈSE* The Relationships and Influence of Three Selected Variables on the Aerobic Capacity of an Urban Canadian Community

UNIVERSITY/*UNIVERSITÉ* University of Alberta, Edmonton

DEGREE FOR WHICH THESIS WAS PRESENTED/
GRADE POUR LEQUEL CETTE THÈSE FUT PRÉSENTÉE Ph D.

YEAR THIS DEGREE CONFERRED/*ANNÉE D'OBTENTION DE CE DEGRÉ* 1974

NAME OF SUPERVISOR/*NOM DU DIRECTEUR DE THÈSE* Dr. RBJ Macnab.

Permission is hereby granted to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

L'autorisation est, par la présente, accordée à la BIBLIOTHÈQUE NATIONALE DU CANADA de microfilmer cette thèse et de prêter ou de vendre des exemplaires du film.

L'auteur se réserve les autres droits de publication; ni la thèse ni de longs extraits de celle-ci ne doivent être imprimés ou autrement reproduits sans l'autorisation écrite de l'auteur.

DATED/*DATÉ* Oct 2/74 SIGNED/*SIGNÉ* Arthur Quinney

PERMANENT ADDRESS/*RÉSIDENCE FIXÉ* 2226 Josephine St.
Sudbury, Ont.

NL-91 (11-73)

THE UNIVERSITY OF ALBERTA

THE RELATIONSHIPS AND INFLUENCE OF THREE SELECTED VARIABLES ON THE AEROBIC CAPACITY OF CITIZENS OF AN URBAN CANADIAN COMMUNITY

by

© H. ARTHUR QUINNEY

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF PHYSICAL EDUCATION

EDMONTON, ALBERTA

FALL, 1974

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "The Relationships and Influence of Three Selected Variables on the Aerobic Capacity of Citizens of an Urban Canadian Community" submitted by Henry Arthur Quinney in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Physical Education.

Ross B.J. Macnab
Supervisor

S.W. Mendryk

H. Scott

R.L. Mirwald
External Examiner

Date Sept 27/74

ABSTRACT

The purpose of this research was to investigate the relationships of physical activity level, smoking habits, and fatness as they contribute to the placing of an individual into a high or low aerobic capacity group. Inclusion of both sexes and a wide age range (14 to 74 years) in the study allowed between age group comparisons and between sex comparisons. Tests on 1230 male and female volunteer subjects provided the data for the study.

The following test data was obtained on each subject: aerobic capacity (Astrand-Ryhming nomogram), triceps fat, height, weight, age, physical activity level and smoking habits.

Subjects were grouped by age and sex. Within these 12 groups high and low aerobic capacity groups were created and found to be significantly different on the stratifying variable (predicted $\dot{V}O_{2\ max}$).

Multivariate analysis was employed to examine the combined effect of physical activity level, smoking habits and fatness in differentiating high and low aerobic capacity groups. On the basis of this analysis it was concluded that these three variables combined were significantly different between the aerobic capacity groups for male and female age groups 14 to 19 years, 30 to 39 years, 40 to 49 years and for male age group 20 to 29 years. The remaining male

and female groups 50 to 59 years, 60 to 74 years and female group 20 to 29 years did not display a significant difference between the aerobic capacity groups on the three variables. Discriminant function analysis revealed that fatness was the most important variable in differentiating high and low aerobic capacity groups in male and female groups 30 to 39 years and 40 to 49 years and in male age groups 14 to 19 years and 20 to 29 years. The most important variable in the remaining female group 14 to 19 years was physical activity level. The second most important variable was physical activity level in male and female age groups 30 to 39 years and 40 to 49 years and male age group 14 to 19 years. The variable which was second in importance in male age group 20 to 29 years was smoking habits and in female age group 14 to 19 years was fatness. The least important variable was smoking in male and female age groups 14 to 19 years, 30 to 39 years and 40 to 49 years. The least important variable in the male age group 20 to 29 years was physical activity.

Multivariate analysis of variance applied to complete male and female data showed that for male subjects considered in total and for female subjects considered in total, the combined effect of physical activity level, smoking habits and fatness was significantly different between high and low aerobic capacity groups. Consideration of the variables individualy in this context showed that smoking was not significantly different between high and low capacity

groups but physical activity levels and fatness were significantly different. An overall significant difference in physical activity level, smoking habits and fatness between the six age groups for both male and female subjects was also obtained.

Male-female comparisons revealed significant differences in $\dot{V}O_{2\ max}$ between both high and low aerobic capacity males and females. It was concluded that high aerobic capacity male and female groups were significantly different from each other at each age level on the combined effect of the three variables. Individual comparisons of the variables showed that high aerobic capacity males and females differed significantly in fatness but not in physical activity level or smoking habits. Low aerobic capacity groups analysis produced the same results with the exception of age group 14 to 19 years in which individual comparisons revealed a significant difference in physical activity level between male and female subjects as well as the difference in fatness.

Discriminant function analysis showed that the most important variable in differentiating high and low aerobic capacity male subjects from female subjects was fatness. Physical activity level and smoking habits appeared to be relatively unimportant in this regard.

ACKNOWLEGEMENTS

The author wishes to acknowledge the contribution of Dr. R.B.J. Macnab (Chairman and Advisor) to the completion of the requirements for the Ph. D. degree and in particular to the completion of the thesis. For these contributions the author extends his sincere thanks.

Special thanks are extended to Dr. D.A. Bailey, University of Saskatchewan, Saskatoon, for permission to use the data and his advice in undertaking this project.

The author wishes to thank Dr. R.G. Glassford, Dr. S. Mendryk, Dr. H. Scott and Dr. B. Sproule for serving on the thesis committee and to Dr. R. Mirwald of the University of Saskatchewan, Saskatoon, for serving on the examining committee.

Thanks are also extended to Mr. C. Weese for his assistance in data handling and to Dr. T. Maguire for his advice on data analysis.

A very special thank you to my wife, Peggy, for her assistance and encouragement.

TABLE OF CONTENTS

CHAPTER PAGE

I STATEMENT OF THE PROBLEM 1
- Introduction 1
- The Problem 3
- Justification of the Problem 4
- Limitations of the Study 5
- Delimitations of the Study 6
- Definition of Terms 6

II REVIEW OF THE LITERATURE 9
- Aerobic Capacity as a Measure of Fitness. 9
- Predicting Aerobic Capacity from Submaximal Exercise 12
- Aerobic Capacity - Age and Sex 21
- Aerobic Capacity and Physical Activity . 28
- Aerobic Capacity and Smoking 35
- Aerobic Capacity and Body Composition . . 41

III METHODS AND PROCEDURES 54
- The Sample 54
- Description of Test Items and Questionnaire 56
  - Aerobic Capacity 56
  - Skinfold Measurement 58
  - Physical Activity Self-Rating 58

CHAPTER PAGE

Smoking Habits 58

Equipment and Calibration 59

Testing Sites 62

Testing Procedures 64

Data Handling 67

Data Analysis 68

Selection and Substantiation of High and Low Aerobic Capacity Groups . . . 68

Multivariate Analysis Within Age Groups 69

Multivariate Analysis Between Age Groups 71

Male-Female Aerobic Capacity Groups . 72

Multivariate Analysis Between Male-Female Groups 73

IV RESULTS AND DISCUSSION 75

Results 75

Physical Characteristics of the Subjects 75

Predicted $\dot{V}O_{2\ max}$ Mean Values 78

Substantiation of High and Low Aerobic Capacity Groups by Analysis of Variance 78

Mean Values for Variables 81

Multivariate Analysis Within Age Groups 93

Hotellings' T^2 Test 93

Discriminant Function Analysis . . 95

Multivariate Analysis Between Age Groups 97

Two Way MANOVA 97

Discriminant Function Analysis . . 98

CHAPTER PAGE

Substantiation of Male-Female Aerobic Capacity Differences 99

Multivariate Analysis Within High and Low Male-Female Capacity Groups . . . 100

Hotellings' T^2 Test 100

Discriminant Function Analysis . . 101

Discussion 108

V SUMMARY, CONCLUSIONS AND RECOMMENDATIONS . . . 125

Summary 125

Conclusions 130

Recommendations for Further Research . . 134

* * *

REFERENCES 136

* * *

APPENDICES 153

APPENDIX A: Initial Screening Questionnaire . 154

APPENDIX B: Fitness and Activity Appraisal . 156

APPENDIX C: Anthro-Strength Data Sheet . . . 159

APPENDIX D: Test Administrator Data Sheet . . 161

APPENDIX E: Quit Code 163

APPENDIX F: Data Coding Form 165

APPENDIX G: Test Information for Subjects . . 167

APPENDIX H: Statistical Analysis of Data Summary Tables 169

APPENDIX I: Raw Data 185

LIST OF TABLES

TABLE	DESCRIPTION	PAGE
I	6 X 2 Multivariate Analysis of Variance With Fixed Effects and Unequal Observations Per Cell	71
II	Physical Characteristics of Female Subjects Aged 14 to 74, By Age Group and Aerobic Capacity Group	76
III	Physical Characteristics of Male Subjects Aged 14 to 74, By Age Group and Aerobic Capacity Group	77
IV	Predicted $\dot{V}O_{2\ max}$ Mean Values and Standard Deviations for Male and Female Subjects . . .	79
V	Mean Values and Standard Deviations for Male Subjects for Physical Activity Level, Smoking Habits and Triceps Fat	82
VI	Mean Values and Standard Deviations for Female Subjects for Physical Activity Level, Smoking Habits and Triceps Fat	83

LIST OF FIGURES

FIGURE PAGE

1. Frequency Distribution of Male and Female Subjects 55
2. Mean Physical Activity Level Values for Male Subjects 85
3. Mean Smoking Scores for Male Subjects 86
4. Number of Male Smokers Expressed as a Percentage 87
5. Mean Triceps Skinfold Measures for Male Subjects 88
6. Mean Physical Activity Level Values for Female Subjects 89
7. Mean Smoking Scores for Female Subjects . . . 90
8. Number of Female Smokers Expressed as a Percentage 91
9. Mean Triceps Skinfold Measures for Female Subjects 92
10. Mean Physical Activity Level Values for High Aerobic Capacity Male and Female Subjects . . 102
11. Mean Smoking Values for High Aerobic Capacity Male and Female Subjects 103
12. Mean Triceps Skinfold Values for High Aerobic Capacity Male and Female Subjects 104
13. Mean Physical Activity Level Values for Low Aerobic Capacity Male and Female Subjects . . 105
14. Mean Smoking Scores for Low Aerobic Capacity Male and Female Subjects 106
15. Mean Triceps Skinfold Values for Low Aerobic Capacity Male and Female Subjects 107

FIGURE PAGE

16. Mean $\dot{V}O_{2\ max}$ Values for Male Subjects from this Study Compared to Data from the Literature . . 113

17. Mean $\dot{V}O_{2\ max}$ Values for Female Subjects from this Study Compared to Data from the Literature 114

18. $\dot{V}O_{2\ max}$ Values for Low Aerobic Capacity Male and High Aerobic Capacity Female Subjects . . 115

19. Triceps Skinfold Measures For Male Subjects from this Study Compared to Data from the Literature 116

20. Triceps Skinfold Measures for Female Subjects from this Study Compared to Data from the Literature 117

LIST OF PHOTOGRAPHIC PLATES

PLATE DESCRIPTION PAGE

1. The Main Testing Area Showing Sixteen Subjects Being Tested Simultaneously 63

CHAPTER I

STATEMENT OF THE PROBLEM

INTRODUCTION

The level of physical activity, smoking habits, and fatness have been considered to be the three main variables in determining physical fitness level (142). The fitness level of Canadians has been described as very poor on a number of occasions (146, 157) and the initial analysis of data gathered from a large sample of the population of the city of Saskatoon (16) revealed that the cardiovascular fitness of Canadians is not improving and, in fact, is generally lower than that reported in 1966 (157). As a result of this low level of physical fitness, Canadians are becoming more prone to cardiac disease which has been shown to be a multi-factorial disease involving physical activity level, smoking habits, age, diet, stress level, and heredity (95, 176). Recent information on the prevalence of heart disease in the Canadian population would support this suggestion (36).

A renewed emphasis on increasing physical fitness levels of Canadians and peoples in developed countries generally (U.S.A., Britain, Germany) has been observed in the past two or three years. This interest undoubtedly stems from the positive health benefits associated with the increased functional capacities which accompany a high level of physical fitness. Possible decreases in the cost of medical care programs and the human element of helping individuals enjoy the realization of their potential are motivating factors in this renewed emphasis.

Many exercise specialists and medical personnel have been well aware of the above problems for a number of years. A campaign to make the public of Canada aware of their present low level of physical fitness and to provide some type of motivation to correct these health problems is now under way on several fronts. Sport Participation Canada, ReNu (Manitoba) and other provincial government programs and cardiac prevention and rehabilitation programs in all parts of Canada are actively promoting physical activity.

To provide a form of motivation for Canadians to become more physically active, a groups of Canadian exercise and health specialists suggested the development of a Canadian home test of physical fitness (128). Sport Participation Canada took the lead in asking Dr. D.A. Bailey from the University of Saskatchewan and Dr. R.J. Shephard of the University of Toronto for assistance in developing and providing normative data for a "Home Test of Physical Fitness for Canadians". Subsequently, a research proposal was submitted to Recreation Canada to fund the project with Dr. Bailey as principal investigator and Dr. Shephard as principal consultant. Saskatoon, Saskatchewan, was selected as the site for the project for a number of reasons, among which was the fact that Saskatoon had been selected as a "Demonstration Community" by Sport Participation Canada, and as such, much ground work had been done in establishing a rapport with citizen groups and the media and in citizen readiness for such a project.

The preparatory work for the testing was completed in May, 1973 and testing commenced during late May with completion during the last week of June. The scope of the data generated has opened many possibilities for meaningful evaluation by persons interested in the study and understanding of physical fitness over and above the original purpose of the study. It is with the consent of the principal investigator, Dr. D.A. Bailey, that the data collected has been made available to the author.

THE PROBLEM

The influence of three selected variables on the predicted aerobic capacity of men and women aged 14 to 74 years living in Saskatoon, Saskatchewan, was studied under the following specific purposes:

1) To determine the relationships of physical activity level, smoking habits and fatness to the placing of individuals in a high or low aerobic capacity group.

2) To determine if the relationships of physical activity level, smoking habits, and fatness are consistent between age groups in placing individuals in a high or low aerobic capacity group.

3) To examine the differences in aerobic capacity between male and female subjects in similar aerobic capacity groups in terms of physical activity level, smoking habits and fatness.

JUSTIFICATION OF THE PROBLEM

Cardiac disease has come to be known as a multifactorial disease with physical activity level, smoking habits, age, diet, stress level, and heredity all contributing to presence or absence of the disease (95, 176). Many studies have examined these factors as they contribute to the presence or absence of disease singly, but few have tried to determine how some of these factors act in combination to discriminate healthy from individuals with coronary heart disease (44, 99, 181, 185).

Low physical fitness as measured by aerobic capacity must also be considered a multifactorial problem. Robinson et al. (142) on the basis of tests conducted over a thirty-one year span have concluded that "....the aerobic work capacities of men in the forty to fifty-two year age range depend largely on their habits of exercise, diet and smoking ....". As well, common to most advice being given to persons on how to proceed to improve physical fitness (aerobic capacity) from both physicians and physical educators are weight control, cessation of smoking and increasing levels of physical activity.

The purpose of this research was to investigate the relationships of physical activity level, smoking habits and fatness as they contribute to the placing of an individual in a high or low aerobic capacity group. It is hoped that this information can then in turn be used to help advise people of the relative importance of these factors in improving their level of physical fitness. The inclusion of both sexes and a wide range of ages will allow individualization if age and sex variations in the relationships of these factors are present.

LIMITATIONS OF THE STUDY

1. The subjects in the study were volunteers and thus a bias may have been built into the data collected.

2. Temperature and humidity in the testing environment were not strictly controlled.

3. The activites of the subjects prior to testing, that is, smoking, eating, physical activity, could not be controlled but subjects were asked to abstain in initial instructions.

4. The validity of the test items and their limitations in accurately measuring aerobic capacity, fatness physical activity level and smoking habits must be recognized.

5. Subjects were, in most cases, unfamiliar with the bicycle ergometer but all were familiar with test procedure and the testing environment.

6. There was no control over the time of day that

the subjects were tested.

7. The study was limited by equipment error and the technical error of the investigators in collecting the data.

DELIMITATIONS OF THE STUDY

This study is delimited to the 1544 subjects, 845 female and 699 male volunteer participants ranging in age from 14 to 74 years that were tested.

DEFINITION OF TERMS

(1) Age Group: Subjects are categorized into one of six age groups and will be referred to under the appropriate numbered group:

Age Group 1: subjects age range 14 to 19 years
Age Group 2: subjects age range 20 to 29 years
Age Group 3: subjects age range 30 to 39 years
Age Group 4: subjects age range 40 to 49 years
Age Group 5: subjects age range 50 to 59 years
Age Group 6: subjects age range 60 to 74 years

(2) Body Fat: the amount of the human body that is made up of adipose tissue. For the purposes of this study, the thickness of a double layer of subcutaneous fat and skin measured by the use of a Harpenden caliper is used as an estimate of body fat. The site utilized was the triceps.

(3) Maximal Oxygen Consumption: ($\dot{V}O_{2\ max}$, maximal oxygen uptake, maximal oxygen intake, aerobic capacity), the maximal amount of oxygen that can be taken in and transported to

the working muscle per unit time during maximal exercise involving large muscle groups, attained when increases in work load result in no further increase in oxygen consumption.

(4) Non-smoker: a person who does not smoke cigarettes, cigars or a pipe and so indicates in a questionnaire.

(5) Physical Activity Level: the amount of time spent in vigorous physical activity. For the purposes of this study the individual's physical activity level is his self-perceived estimation of time spent in vigorous physical activity.

(6) Physical Fitness: (endurance fitness, physical work capacity), the ability to perform prolonged hard physical work; this implies that a major factor is the capacity of the oxygen transport system to supply oxygen to the site of the working muscle.

(7) Predicted Maximal Oxygen Consumption: an estimation of $\dot{V}O_2$ max based on the linear relationship between oxygen consumption and heart rate and in this study calculated by means of the Astrand-Ryhming Nomogram (13).

(8) Smoker: a person who habitually smokes cigarettes, cigars or a pipe and so indicates in a questionnaire.

(9) Steady State: a physiological equilibrium in which oxygen consumption is equal to oxygen cost. For the purpose of the predicted $\dot{V}O_{2\ max}$, Astrand and Ryhming criterion (11) of two or more consecutive pulse rate readings separated by one minute intervals that did not differ by more than ±5 beats per minute was used.

(10) Submaximal Work Load: a work load that elicits a steady state heart rate response between 120 and 170 beats per minute.

CHAPTER II

REVIEW OF THE LITERATURE

AEROBIC CAPACITY AS A MEASURE OF FITNESS

Maximal oxygen consumption (aerobic capacity) has been measured and studied in humans with reference to metabolism for over fifty years (87). Much has been written and many controversies have arisen over the use and, in some minds, misuse of this physiological parameter.

The use of the aerobic capacity as a single best measure of physical fitness will still bring argument. Most would agree, however, that as stated by Hettinger et al. (86) "during prolonged heavy physical work, the individuals' performance capacity depends largely on his ability to take up, transport and deliver oxygen to the working muscle."

Several other researchers have reiterated this statement in principle in a number of papers; Astrand (14), Rodahl (143), Taylor et al. (178), Newton (125) and Macnab (109). Macnab (109) has suggested that substantiation of aerobic capacity as a best single measure to perform hard physical work has been demonstrated in three basic types of investigations. First, athletes have been shown to have significantly greater aerobic capacity than a group of non-athlete controls. Second, studies have established "correlational" relationships between aerobic capacity and external criteria of performance. Third, increases in aerobic capacity have been demonstrated during a season of athletic training. Macnab suggests that caution be used in interpreting these results, however. He suggests other criteria must be taken into account when evaluating performance of physical work--task specificity, motivation, strength and anaerobic capacity.

Cumming (46) agrees that care must be taken in the use of aerobic capacity measures. He suggests that the maximum oxygen uptake test should not be used as the sole criterion of fitness at least until some discrepancies are explained and the methods standardized.

Astrand (9) states that "a measure of the individual's maximal oxygen uptake gives valuable information about 1) the maximal work power and 2) the functional capacity of the oxygen transport system." Astrand also adds a note of caution about the "bold conclusions" that may be wrongly drawn from knowledge of aerobic capacity measures. In many activities the demand on anaerobic work power, technique, strength and so on is more pronounced than the demand on aerobic power. He emphasizes, however, that when large muscle groups are working at a high intensity for a minute or longer, the maximal aerobic power is of decisive importance.

Davies (51) accepts aerobic capacity as a best measure of physical fitness with some reservation. However, he states that maximal oxygen consumption does remain a decisive measure of the potential ability to perform at a high intensity with large muscle groups for periods of time up to one hour. Aerobic capacity measurement in population studies of physical fitness should be encouraged for this reason. Davies suggests that for prolonged hard physical work (distance running) the ability to utilize a higher proportion of the aerobic capacity for a given period of time is a much better indicant of performance than aerobic capacity. This suggestion has been borne out by Costill et al. (42) who have reported correlations between performance in a 10 mile race and aerobic capacity of $r = -.91$, run time and per cent aerobic capacity at a given speed of $r=-.94$, and run time and per cent maximum heart rate of $r=.98$.

"Although many tests of cardio-respiratory fitness have been proposed in the past few decades, the opinion is now widespread that the directly measured $\dot{V}O_{2\ max}$ should be accepted as the absolute criterion against which other procedures are to be judged. In physiological terms this view seems indisputable, for the $\dot{V}O_{2\ max}$ integrates the performance of each of several 'conductances' concerned in the transfer of oxygen from the atmosphere to the working tissues." (164) This statement was the conclusion reached by an international committee delegated to derive an International Reference Standard of Cardiorespiratory Fitness. This committee also concluded that it would be unrealistic to suggest that $\dot{V}O_{2\ max}$ be measured directly for entire populations. They suggested that difficulty would be encountered in reaching a maximum with "the very young, the elderly and female subjects", while the logistic requirements in terms of medical supervision would be prohibitive.

PREDICTING AEROBIC CAPACITY FROM SUBMAXIMAL EXERCISE

Many researchers and clinicians have recognized the many disadvantages of direct measurement of $\dot{V}O_{2\ max}$ (13, 15, 48, 190). Among the reasons that have been put forward as hindrances in the accurate direct assessment of $\dot{V}O_{2\ max}$ are: 1) sophisticated and expensive equipment necessary; 2) trained technicians and supervision; 3) motivation required to work at required high levels; 4) danger to elderly or patients with circulatory respiratory disease; and 5) time required.

The disadvantages of direct measurement of $\dot{V}O_{2\ max}$ has led several exercise and medical specialists to look to submaximal testing for an estimation of $\dot{V}O_{2\ max}$. Tests based on submaximal exercise data have been put forward by Margaria, Aghemo and Rovelli, 1965 (112), Maritz et al., 1961, (113), Issekuta, Birkhead and Rodahl, 1962, (91) and Astrand and Ryhming, 1954, (13). The earliest of these tests is that of Astrand and Ryhming (13), who developed a nomogram by which $\dot{V}O_{2\ max}$ could be predicted, based on a known work load and the steady state heart rate response to that exercise (6 minutes of exercise). The use of the Astrand-Ryhming nomogram has become very widespread in its application for prediction of $\dot{V}O_{2\ max}$ (159).

The Astrand-Ryhming nomogram was developed from data collected on eighty-six healthy physical education students aged 18 to 30 years. Study on the data revealed that for the men, an average heart rate of 128 beats/minute corresponded to 50% $\dot{V}O_2$ max and 154 beats/minute corresponded to 70% of $\dot{V}O_2$ max. Corresponding values for the women studied were 138 beats/minute at 50% $\dot{V}O_2$ max and 168 beats/minute at 70% $\dot{V}O_2$ max. The standard deviation was in the order of 9 beats/minute. The reasoning used was that a male working at this load with a heart rate of 128 beats/minute and a $\dot{V}O_2$ of 2.3 litres/minute should have a $\dot{V}O_2$ max double this value or 4.6 litres/minute. Using the average maximal heart rates for men and women in the sample and the per cent of maximal oxygen uptake versus the average heart rate elicited, a nomogram was constructed for the prediction of $\dot{V}O_2$ max from submaximal pulse rates (120 to 170 beats). The original nomogram published in 1954 was subsequently modified after further study by I. Astrand and published in 1960 (6). The main alteration was the use of an age correction factor which had elicited several objections to the use of the nomogram for persons outside of the age range from which the nomogram was developed.

Astrand and Rodahl (15) suggest that several tests should be performed at different test loads and mean figures calculated according to the nomogram. They also suggest that the nomogram may be adapted for use of only one test load. Astrand and Rodahl conclude that an evaluation of the maximal effect of the oxygen transportating system based on studies at submaximal work loads or oxygen uptake, should be done with the utmost caution, especially when persons of different age groups are considered. Astrand and Saltin (14) on the basis of other research also recommend that the duration of work in studies of circulation and respiration during submaximal work should exceed 5 minutes to permit adjustment of these systems to the level of exercise.

Taylor et al. (178) have concluded that the physiological basis of the Astrand-Ryhming nomogram is sound: "under carefully standardized conditions in selected homogeneous groups the pulse rate at submaximal levels of work is systematically related to the maximal oxygen intake, it follows that the capacity to perform physical work can be estimated from study of the pulse rate at submaximal work levels."

The accuracy and validity of the Astrand-Ryhming nomogram has been subjected to study by several researchers. Baycroft (20) studied 48 physically active males to predict $\dot{V}O_{2\ max}$. Subjects were tested on the Mitchell, Sproule and Chapman treadmill test for direct measurement of $\dot{V}O_{2\ max}$ and on the bicycle ergometer with prediction of $\dot{V}O_{2\ max}$ with the Astrand-Ryhming nomogram. The correlation between the two tests was r=.67, which was significant at the p=.01 level.

The purpose of a study conducted by Hyde (88) was to investigate the validity of the Astrand-Ryhming nomogram for males and females of secondary school age by comparing values obtained from the Astrand-Ryhming predicted $\dot{V}O_2$ max test with those of the Astrand test for direct measurement of $\dot{V}O_2$ max. Twenty-nine male and twenty-seven female subjects were tested on both tests. Hyde concluded that on the basis of his results, the Astrand-Ryhming prediction was equivalent to the results obtained on the direct $\dot{V}O_2$ max test for the females but that it underestimated the $\dot{V}O_2$ max values for the males. The underestimation for the females was in the order of 5.5% and for the males 10% which are within the values that Astrand and Rodahl (15) have suggested for the test. Hyde (88) also concluded that the Astrand-Ryhming nomogram appears to differentiate between individuals who are in widely different states of training but not between individuals who are in approximately the same state of training.

Glassford and co-workers (76) subjected twenty-four male volunteers 17 to 30 years of age to three direct tests of $\dot{V}O_2$ max, one indirect test (Astrand-Ryhming test) and the Johnson, Brouha and Darling Physical Fitness test. The three direct tests were the Mitchell, Sproule and Chapman Treadmill tests, the Taylor, Buskirk and Henschel Treadmill test and the Astrand Bicycle Ergometer test. The results showed that the treadmill tests and the indirect test yielded significantly higher mean values than did the direct bicycle test. No other significant differences in mean values occured. Correlations between the Astrand-Ryhming prediction and the Mitchell et al. results was r=.77, the Taylor et al. results r=.63 and the Astrand direct test r= .63. All of the correlations were significant. The authors concluded that the Astrand-Ryhming nomogram relationships with direct tests are as good as the relationship between any two direct tests and that the Astrand-Ryhming nomogram appears to produce a good estimation of $\dot{V}O_{2\ max}$ in a population unaccustomed to cycling.

Teraslinna et al. (180) compared the directly measured $\dot{V}O_{2\ max}$ values of 31 sedentary male subjects, 23 to 49 years, with age corrected predicted values for the same subjects. The direct tests were taken on a bicycle ergometer. Before age correction the correlation between the tests was r=.69 and after age correction r=.92. Both of these correlations were significant.

Oja et al. (127) studied direct versus predicted $\dot{V}O_{2\ max}$ measures on forty-eight Finnish soldiers, 30 to 40 years of age. As well as a direct $\dot{V}O_{2\ max}$ test, predicted $\dot{V}O_{2\ max}$ on two tests, Astrand-Ryhming and a test by Van Dobeln (183) and a physical fitness battery developed by Ismail (90) were conducted. The correlation between the Astrand-Ryhming nomogram prediction and the direct measure of $\dot{V}O_{2\ max}$ was r=.542 which led the authors to conclude that the validity of the test to measure $\dot{V}O_{2\ max}$ was "not very good". However, they felt that the Astrand-Ryhming results gave a reasonably valid prediction of young and middle-aged mens' physical fitness as measured by the Ismail battery. The correlation between the fitness test battery and the Astrand-Ryhming test results was r=.849.

Wyndham et al. (191) set out the objective of examining Astrand's premise that heart rate is a linear function of oxygen intake through the range of values and as well to study the reproducibility of heart rate and $\dot{V}O_2$ at various loads. The research was conducted with four highly trained male Bantu miners. The researchers concluded that when heart rate is plotted against $\dot{V}O_2$, the linear relationship which holds for most of the range of values, deviates at the high levels of work towards $\dot{V}O_2$ values higher than would be predicted from extrapolation of the linear part of the curve to maximum heart rate values. Thus there would be a tendency to underestimate the $\dot{V}O_{2\ max}$ through use of the Astrand-Ryhming nomogram. In their subjects the underestimation was in the order of 0.32 ± 0.14 litres of oxygen/minute. The researchers also concluded that the constancy of heart rate at standard work is high.

This research has been criticized because of the fact that the men were working at 5,500 feet altitude and the effect of prolonged hypoxia might cause some discrepancies (6). In defence of the nomogram, I. Astrand also points out that it is not the premise of the nomogram to assume that the heart rate is a linear function of $\dot{V}O_2$ throughout the entire range of values (6).

Maritz et al. (113) tested the three premises for estimating an individual's $\dot{V}O_{2\ max}$ from submaximal data using the Astrand-Ryhming test as the basis. They concluded that: 1) $\dot{V}O_2$ deviates very little from the mean straight line relating oxygen intake and rate of work so that the $\dot{V}O_2$ for a task performed against gravity can be estimated with reasonable precision from the rate of work; 2) the individual variability of the maximum heart rate around the mean in a routine test procedure without the introduction of large errors; 3) the premise that heart rate and $\dot{V}O_2$ are linear functions of each other throughout the entire range of work up to maximal is not strictly valid. These researchers found a bias in the order of 0.3 litres/minute in the straight line relating heart rate and $\dot{V}O_2$ at high levels of work in most individuals. The underestimation of 0.3 litres/minute was found at a $\dot{V}O_{2\ max}$ capacity of 3.0 litres/minute.

Maritz et al. (113) also describe a method by which $\dot{V}O_{2\ max}$ can be predicted from submaximal data through the fitting of a straight line by squares to plots of four pairs of heart rate - $\dot{V}O_2$ values at four rates of work. Using this method (commonly referred to as the Maritz-Wyndham test) they suggest the variance of predicted $\dot{V}O_{2\ max}$ values can be significantly reduced.

Rowell, Taylor and Wang (145) in 1964 tested thirty-four male subjects aged 18 to 24 years using a direct $\dot{V}O_{2\ max}$ treadmill test and the Astrand-Ryhming predictive test. They found that the nomogram underestimated the actual $\dot{V}O_{2\ max}$ by 27 ± 7% and 14 ± 7% in a sedentary group before and after two and a half to three months of training and by 5.6 ± 4% in a group of 10 endurance athletes. Rowell et al. also found that the trained subjects more nearly met the 50% $\dot{V}O_{2\ max}$ heart rate of 128 beats/minute noted by Astrand and Ryhming (13).

Davies (48) working with twenty-five male and nineteen female subjects 20 to 28 years of age studied the premises on which the common procedures for predicting $\dot{V}O_{2\ max}$ are based, that is: 1) the relationship between heart rate and $\dot{V}O_2$ is linear up to and including maximum levels of work; 2) all subjects within a particular age group are able to reach similar maximal heart rates. His results showed that neither premise is [illegible]ly valid. The heart rate - $\dot{V}O_2$ relationship becomes assymptotic at near maximum work and maximum heart rate showed a small but significant correlation with $\dot{V}O_{2\ max}$. Davies found that in subjects with high observed $\dot{V}O_{2\ max}$ that the errors from these two sources tend to cancel out, but in more sedentary subjects the errors combine to produce significant bias towards underestimation. Davies (48) concluded that the above factors together with the natural variability of heart rate response preclude the accurate estimation of $\dot{V}O_{2\ max}$ from either the Astrand-Ryhming nomogram or the Margaria nomogram (112).

Margaria, Aghemo and Rovelli (112), not satisfied with the Astrand-Ryhming nomogram, set about to develop a more accurate means of predicting $\dot{V}O_{2\ max}$. The premises on which their nomogram is based is essentially the same as in the Astrand-Ryhming nomogram. The Margaria procedure, however, requires two work loads with the corresponding heart rate values to produce a regression line for prediction. The mode of exercise is bench stepping. Margaria et al. on the basis of their data claim that their method produces results which are within ±7% of values directly determined. Davies (50) in another study utilizing eighty male subjects 20 to 50 years of age, compared the heart rate - $\dot{V}O_2$ curves in relation to the overall limitations of predicting $\dot{V}O_{2\ max}$ and examined the accuracy of the Astrand-Ryhming, Margaria and Maritz-Wyndham prediction nomograms. The results of this study were similar to his results published one year earlier (48). He concluded, however, that in looking at the variability of maximum heart rate within an age group that the error in this premise was small and well within the expected day to day variation in the estimation of $\dot{V}O_{2\ max}$ from measurement of heart rate and $\dot{V}O_2$. Davies (50) found that the Maritz-Wyndham technique to be the most accurate, followed by the Margaria nomogram and then the Astrand-Ryhming nomogram. The variation in accuracy was only small, however, with the Maritz-Wyndham and Margaria methods only showing a 2% improvement over the Astrand-Ryhming nomogram. In using the Astrand-Ryhming nomogram, Davies suggests that the accuracy increases as the exercise heart rates are higher in the 120 to 170 beats/minute range. The overall accuracy calculated for the Astrand-Ryhming nomogram was ± 12%. Davies (50) concludes that predictive methods provide only a crude guide to an individual's ability to perform at maximum effort; for accurate analysis of aerobic capacity there appears to be no alternative but to measure directly. Considering all of the disadvantages and limitations of utilizing submaximal exercise data for the prediction of aerobic capacity, it is still the best available technique when dealing with large populations or in field studies (157, 159, 163). This opinion seems to be prevalent and until more accurate techniques are available the inaccuracies associated with prediction of aerobic capacity must be accepted. Minimizing the possible inaccuracy may be accomplished with careful standardization of procedure, accurate calibration of instruments, and trying to select work loads that result in heart rate response as high as possible in the acceptable range.

Shephard (162), recognizing the widespread use of the Astrand-Ryhming nomogram, developed a computer program for the rapid and accurate calculation of predicted $\dot{V}O_{2\ max}$ from submaximal exercise data utilizing the Astrand-Ryhming nomogram. This program incorporated the age correction factors recommended by I. Astrand (6) and outputs both $\dot{V}O_{2\ max}$ in litres/minute and millilitres/kilogram/minute.

AEROBIC CAPACITY - AGE AND SEX

The most complete early study of physical fitness in relation to age was that of Robinson (141) in 1938. Ninety-three healthy male non-athletes aged six to ninety-one years served as subjects in tests of resting cardio-respiratory function and work capacity. Robinson noted a decline in maximum heart rate with age from a median of 198 beats at age 6 to 158 beats in three men averaging 75 years of age.

The $\dot{V}O_{2\ max}$ for Robinson's subjects when expressed as litres/minute reached its highest mean level 3.61 for the group with a mean age of 17.4 years (16 to 19 years). This group he suggests is the post adolescent group. The group means show a gradual decline in both directions from this peak of 0.98 litres/minute in the younger boys (mean age 6.1 years) and to 1.71 litres/minute in the men in the eighth decade (N=3, mean age 75.0 years). When the $\dot{V}O_{2\ max}$ is expressed as a function of body weight, the 17 year old group is still the highest, 52.8 ml/kg/min, but the immediately pre-adolescent group (8 to 12 years) is very close at 52.1 ml/kg/min. The adoscent boys are somewhat lower with a mean $\dot{V}O_{2\ max}$ of 46.7 ml/kg/min (mean age 14.1 years, 13 to 15 years). From the peak of 52.8 ml/kg/min in the 16 to 19 year group the $\dot{V}O_{2\ max}$ as a function of body weight decreases steadily with advancing age. This drop Robinson associates with a decline in physical activity level of men once they reach about 20 years of age. Robinson measured $\dot{V}O_2$ directly with subjects working on a treadmill.

Astrand (8) reports results of tests on 112 female and 115 male subjects between the ages of four and thirty years for $\dot{V}O_{2\ max}$ measured on both treadmill and bicycle ergometer. He concludes that for all the male age groups over seven years the $\dot{V}O_{2\ max}$ expressed as a function of body weight was fairly constant with values ranging from 56 to 59 ml/kg/min.

The subjects under 20 years were "normal" healthy school children; those over 20 were physical education students who might be expected to be considerably higher in aerobic capacity than their less active counterparts. Boys and girls in the younger age groups (4 to 9 years) exhibit essentially the same $\dot{V}O_{2\ max}$. Once 12 years of age is reached the males have developed a significantly larger $\dot{V}O_{2\ max}$, approximately 17%, than their female counterparts. For adults the $\dot{V}O_{2\ max}$ averaged 4.11 litres/minute for forty-two men and 2.90 litres/minute for forty-four women (29% lower).

Metheny et al. (116) compared a group of seventeen females, 20 to 27 years, with a group of thirty males, 19 to 23 years in terms of their $\dot{V}O_{2\ max}$ determined directly on a treadmill. The males were significantly higher with values of 51.3 litres/minute to 40.9 litres/minute reported. A comparison of the eight best females with the 10 poorest males still shows a significantly higher mean value for the males.

Von Dobeln (182) measured and compared body weight, $\dot{V}O_{2\ max}$ and per cent body fat for 35 young adult male subjects and 34 young adult female subjects. The male subjects exhibited a 10% higher body weight than the females (69.3 kg.

to 62.8 kg.) and a 28% higher $\dot{V}O_{2\ max}$ (3.91 to 3.06 litres/minute). The females had a greater amount of body fat, 20.3% compared to 10.6% for the males.

Hermansen and Andersen (85) working with forty-three young Norwegian men and women measured $\dot{V}O_{2\ max}$ and estimated body fat based on skinfold measures. The male group consisted of fourteen highly trained athletes and twelve students with mean $\dot{V}O_{2\ max}$ of 71 and 44 ml/kg/min respectively. There were five highly trained female athletes in the female group ($\dot{V}O_{2\ max}$ 55 ml/kg/min) and twelve students ($\dot{V}O_{2\ max}$ 38 ml/kg/min). The overlap of male and female values for aerobic capacity is quite evident and special note should be made. The 55 ml/kg/min mean value for the five highly trained female cross country skiers in this group is significantly higher than the mean value of 44 ml/kg/min for the twelve untrained male students.

Knuttgen (100) studied 95 male and 95 female high school students with mean ages of 16 years 10 months and 16 years 7 months respectively. His results show that the female $\dot{V}O_{2\ max}$ is 57% that of the boys expressed in litres/minute and 67% when expressed as a function of body weight. Knuttgen also reported that the females resting heart rate was significantly higher than that of the males but that maximum heart rate was not (193.5 to 195.8 beats/minute).

Irma Astrand has devoted much time to the study of age and sex variations in work capacity and other physiological variables. Based on direct measurements of $\dot{V}O_{2\ max}$ in

350 individuals ranging in age from four to sixty-five years, Astrand (7) concludes that before puberty there is no significant difference in aerobic work capacity between boys and girls but in adult life the capacity of women is only seventy to seventy-five per cent that of men. In both sexes there is a peak at the age of 18 to 20 years followed by a gradual decline in aerobic capacity. At age 65 years the mean value is about 70% of that of a twenty-five year old. The $\dot{V}O_{2\ max}$ for a 65 year old man is the same as that typical of a 25 year old woman. Astrand found that intergroup variability was quite large with considerable overlap between age categories and between sexes. Astrand also noted a decrease in maximal heart rate with increasing age, a gradual decline from 210 beats/minute around age 10 to 160 beats/minute in the sixties. Based on this data Astrand (6) produced age correcting factors for the prediction of $\dot{V}O_{2\ max}$ using submaximal exercise and the Astrand-Ryhming nomogram.

Macnab, Conger and Taylor (110) measured $\dot{V}O_{2\ max}$ on twenty-four female and twenty-four male first year university students with two tests (treadmill and bicycle ergometer) as well as PWC_{170} and body density. These researchers found that men were higher than women ($p < 0.01$) when values were expressed as litres/minute, ml/kg/min or ml/kg fat free wt/[illegible]n. The male values observed were 51.7 ml/kg on the Mitchell et al. test and 46.47 ml/kg on the Astrand ergometer test. The female values were 39.06 ml/kg and 35.67 ml/kg on the two tests. Macnab et al. reviewed results of other researchers and found that male-female differences in $\dot{V}O_{2\ max}$ varied from 15% to 25%.

Dawson and Hellebrandt (53) followed one subject through the ages of forty-one to seventy-one years. During this time period they observed a gradual decline in working capacity, becoming at age 71 about 50% of what had been at 41 years.

Dill, Horwath and Craig (56) and Dill and Consolazio (57) report data on one subject (Dill) from 37 to 70 years of age. A gradual decline in both $\dot{V}O_{2\ max}$ and maximal heart rate was reported from 3.28 litres/minute and 172 beats/minute at age 37 to 2.30 litres/minute and 150 beats/minute at seventy.

I. Astrand (5) administered $\dot{V}O_{2\ max}$ tests (bicycle ergometer) on 81 male Swedish truck drivers, fifty to sixty-four years. When the drivers were divided into 5 year age brackets the expected decline in aerobic capacity was observed, 2.55 litres/minute for the 50 to 54 year old group, 2.43 litres/minute for the 55 to 59 year old group and 2.14 litres/minute for the 60 to 64 year old group.

Davies (49) tested eight healthy men 20 to 50 years of age. He found that only F.V.C., F.E.V. and maximal heart rate were associated with the decline in $\dot{V}O_{2\ max}$ with age which was also observed with his subjects.

Eighty-four male construction workers age 30 to 70 years were tested at submaximal and maximal work on a bicycle ergometer to monitor age related change in $\dot{V}O_{2\ max}$ and to attempt to produce a better predictive equation for $\dot{V}O_{2\ max}$ by Von Dobeln, I. Astrand and Bergstrom (183). The expected decline in $\dot{V}O_{2\ max}$ and maximum heart rate with age was observed: 1) 30 to 39 years: 3.17 litres/minute (178 beats/minute); 2) 40 to 49 years: 2.72 litres/minute (171 beats/minute); 3) 50 to 59 years: 2.59 litres/minute (163 beats/minute); 4) 60 to 70 years: 2.29 litres/minute (155 beats/minute). The work involving multiple regression analysis to determine optimal prediction from submaximal work showed that: 1) body size doesn't add to the prediction; 2) if submaximal heart rate alone is used it is no better than age alone; 3) the best prediction was based on submaximal heart rate, age and maximal heart rate; 4) precision of prediction is reduced just slightly if maximal heart rate is not used and submaximal heart rate and age are.

Parizkova et al. (132) studied one group of young physical education students (20.76 years) and two groups of older men, one sedentary (72.49 years) and one active in sports activities (73.9 years). The aerobic capacity between the young group and both old groups while higher than the sedentary group (1.393 litres/minute to 1.181 litres/minute) were not significantly higher. These researchers observed that the decline in functional capacity measured as the $\dot{V}O_{2\ max}$ runs parallel to a decrease of lean body mass in senescence. They also found that the capillary to fibre ratio was significantly higher in the young group, that is, more favorable with regard to oxygen and nutrient supply to muscle.

AEROBIC CAPACITY AND PHYSICAL ACTIVITY

Training studies in which vigorous physical activity is introduced as an intervening variable between measures of aerobic capacity have demonstrated that individuals can increase their aerobic capacity up to 33% (147). Frick et al. (75) measured the physical work capacity of fourteen sedentary men nineteen to twenty-six years of age before and after two months of hard basic training. The mean PWC_{170} before training was 959 kpm/min and after training 1072 kpm/min, a change of 113 kpm/min. This difference was significant, $p < 0.01$.

Skinner et al. (167) trained fifteen previously sedentary men 35 to 55 years of age on a six month program of endurance running and calesthenics. The time for a mile run was significantly decreased post-training as well as the time required to reach a heart rate of 150 beats/minute exercising on a bicycle ergometer. Pre-test time required to reach the criterion heart rate was 8.86 minutes while post-test time was 10.79 minutes. This difference was found to be statistically different, $p = .001$. Skinner et al. concluded that a program of physical activity produces changes in functional capacity and body composition that run counter to the trend usually seen with aging.

Naughton and Nagle (124) pretested 18 men with an average age of 41 years for $\dot{V}O_{2\ max}$ before training them in a program involving three, thirty minute sessions per week of warm up, calesthenics and running. Before training the mean $\dot{V}O_{2\ max}$ was 31.3 ml/kg with post-test $\dot{V}O_{2\ max}$ measuring 36.8 ml/kg. This difference was significant at $p < .001$.

Parallel studies by Grimby and Saltin (79) and Saltin and Grimby (149) have reported data on athletes who have continued to train over a mean period of 20 years. Grimby and Saltin (79) measured $\dot{V}O_{2\ max}$ of 33 men aged 42 to 68 years who had been training continuously since adolescence. The aerobic capacity of these men is approximately 30% above the average values reported by I. Astrand (6). Saltin and Grimby (149) measured the $\dot{V}O_{2\ max}$ of 29 former male athletes 45 to 70 years who had discontinued training for at least ten years. The former athletes who were not training were still above the average for sedentary middle aged men but were approximately 25% lower than the values for the still active athletes of the same ages.

Ribisl (140) trained fifteen, sedentary middle aged (40.0 ± 5.7 years) for five months on a running program (35 minutes per session, three times per week). Direct measurement of $\dot{V}O_{2\ max}$ was performed on a treadmill test before and after the training period. Statistically significant increases in $\dot{V}O_{2\ max}$, both in litres/minute and ml/kg/min were reported (3.36 ± .43 litres/minute or 40.1 ± 5.1 ml/kg/min).

Saltin et al. (150) reported improvements in $\dot{V}O_{2\ max}$

and heart rate at standard exercise for forty-two men aged 34 to 50 years after 8 to 10 weeks of a conditioning program. Pre-training mean $\dot{V}O_{2\ max}$ was 2.89 litres/minute and the post-training value was 3.44 litres/minute. After training the heart rate at a submaximal exercise load was 10 to 20 beats lower.

Hartley et al. (81), working with fifteen previously sedentary men aged 38 to 55 years, noted improved $\dot{V}O_{2\ max}$ in all subjects after an endurance training program of running two to three half hours per week for eight to ten weeks. The mean $\dot{V}O_{2\ max}$ increased fourteen per cent from 2.68 litres/minute to 3.06 litres/minute. These authors also noted a decrease in heart rate at a given submaximal exercise level in the range of 8 to 17 beats/minute.

Training effects in adolescent boys was studied by Ekblom (62) who measured the $\dot{V}O_{2\ max}$ of thirteen 11 year old boys and then split the group into training (six) and non-training (seven) groups. Both groups were retested after six months. The training group showed an increase of 15% in $\dot{V}O_{2\ max}$ (2.15 to 2.48 litres/minute) while the control group showed no change. Five of the six boys in the training group continued to train for a further 26 months. $\dot{V}O_{2\ max}$ increased 55% over the total 32 months, vital capacity increased 54% and heart volume increased 43%. All of these increases were greater than what might have been expected from the age dependant increases in body size in terms of body height.

Elderly subjects are also quite trainable in terms of $\dot{V}O_{2\ max}$ as indicated by a study reported by deVries (54). One hundred twelve male subjects aged 51 to 87 years were pre-tested and then retested at 6, 18 and 42 weeks of an exercise program. The exercise program consisted of one hour per day, three days per week of stretching, calesthenics and swimming or jogging. After six weeks the $\dot{V}O_{2\ max}$ increased significantly (7.03%) and after forty-two weeks had increased more than 10%. Other results showed vital capacity increased 19.6%, physical work capacity significantly increased and per cent body fat decreased significantly.

Seigal et al. (151) trained nine men aged 32 to 59 years who had been blind for 10 years or more. These men had been sedentary with a stable activity pattern. The training program was an interval program of cycling on a bicycle ergometer three times per week (four, 3 minute exercise periods with 3 minute rest periods). Subjects were pre-tested and retested at seven and fifteen weeks. Significant increases in $\dot{V}O_{2\ max}$ were reported for all subjects. After fifteen weeks five subjects continued to exercise once a week for twenty-nine weeks while four subjects returned to their sedentary habits. Both groups decreased significantly in $\dot{V}O_{2\ max}$ but the group that trained only once a week maintained a level similar to that they had attained after seven weeks of training while the sedentary group returned to a level just slightly above their original level.

Barry et al. (18) working with male (five) and female (three) subjects (mean age 70 years) trained them three times per week for three months on a bicycle ergometer. Five control subjects were also tested. Aerobic capacity was significantly increased over the levels attained by the training group.

Saltin(147) sums up the results of many training studies by saying, "Physical training will produce an improvement in $\dot{V}O_{2\ max}$, that is, the $\dot{V}O_{2\ max}$ of sedentary men can be increased and maintained at a higher level by regular physical activity. The absolute magnitude of improvement will depend upon initial values for $\dot{V}O_{2\ max}$ and on constitutional factors." Astrand and Rodahl (15) report unpublished work by I. Astrand and Kilbom on women aged nineteen to twenty-seven years which indicate the improvement in $\dot{V}O_{2\ max}$ with training is not dissimilar to the results reported for men. Eleven women were tested before and after a training period. The pre-training $\dot{V}O_{2\ max}$ mean value was 1.9 litres/minute and after training 2.18 litres/minute, an increase of 15%.

Andersen (4) commenting on exercise and rate of aging, suggests that middle aged men actively engaged in hard muscular exercise, either in their daily occupation or as recreation, have a higher $\dot{V}O_{2\ max}$ than sedentary men of the same age. He suggests that the regular engagement in strenuous muscular activities may delay functional deterioration with age in such systems as the oxygen transport system.

Cumming (46) also suggests that active participation in physical activity prevents the decline in aerobic capacity that normally occurs with age.

Epidemiological studies have also shown that persons who have a higher level of physical activity also exhibit lower incidence of cardiovascular disease and a higher level of aerobic capacity (64, 69, 70, 72, 95, 111, 120, 122, 136, 195).

McDonough et al. (108) analyzed the results of tests on 86 men aged forty to sixty-nine years of age in terms of $\dot{V}O_{2\ max}$ with varying physical activity levels. Subjects were assigned one of four levels of physical activity ratings based on questionnaire results. The activity groups were labelled sedentary, light, moderate and heavy. $\dot{V}O_{2\ max}$ values were significantly higher in the moderate and heavy activity levels as compared to sedentary and light. The heavy and moderate activity group exhibited approximately a ten year advantage in $\dot{V}O_{2\ max}$ over the more sedentary groups. The primary activity which was used to distinguish between moderate-heavy and sedentary-light was some form of endurance activity.

Accurate assessment of the physical activity levels of large groups has proved to be an extremely difficult and complex problem. Some researchers such as Durnin and Passmore (58) have measured $\dot{V}O_2$ for several common activities and have tried to estimate energy expenditure over prolonged periods of time in this manner. For small groups or when dealing with individuals this method is unquestionably the most accurate. Kannel et al. (96) for use in the Framingham study have developed a means of classifying habitual physical activity based on a twenty-four hour history of usual activity both during leisure and at work. Kannel (95), however, considers this only a crude estimate.

Buskirk et al. (34), Cunningham et al. (47) and Reiff et al (139) have made extensive use of the "Tecumseh Questionnaire" in rating physical activity level. The method used in the "Tecumseh Study" (119) involves a questionnaire which the respondent completes and a subsequent personal interview which takes about 30 minutes to one hour. The data is then objectively scored based on known metabolic requirements for common activities.

Buskirk et al. (34) have suggested that response to simple interview questions designed to determine peak physical activity and the duration of such activity may provide as effective a classification as a much more detailed questionnaire or interview procedure, or both. This group recommends the continued use of a simple three category classification scale for rating leisure physical activity level against occupational activity ratings when studying relatively homogeneous populations such as university employees.

Assessment of habitual physical activity is an ongoing problem and Heinila et al. (83) of the Institute of Occupational Health, Helsinki, Finland, have acted as a clearing house for information since 1965. The variety and number of instruments currently being used to assess this complex variable (physical activity level) continue to make comparisons between studies rather difficult.

AEROBIC CAPACITY AND SMOKING

"It is now well documented that smoking in general, and cigarette consumption in particular, has an adverse influence upon long term health." (160)

Lung cancer, bronchitis and emphysema have all been linked with cigarette smokers and there is some indication that pipe and cigar smokers who inhale are subject to these health problems (194).

Coronary heart disease is also a high risk problem with smokers (106, 121, 144, 152). The risk of death from coronary heart disease for a smoker is around twice that for a non-smoking contemporary and whatever the individual's risk level, twenty cigarettes a day will more or less double it. (144)

Thus, effects of smoking on physical fitness in a very general sense is a negative one. The question of the specific effect of smoking on aerobic capacity is somewhat more controversial.

A study of athletes who were British Empire Games competitors revealed that few athletes smoked, and those who did were boxers, fencers, weight lifters and male athletes in field events. Almost no athletes, who competed in events requiring a high aerobic capacity, smoked (92).

Blackburn, Brozek and Taylor (25) report studies of a total of one thousand ninety three subjects with an age range of seventeen to sixty-seven years. On the basis of work test and the measurement of a number of circulatory parameters, these authors have concluded that there is little evidence for deterioration of cardiovascular "fitness" in smokers.

Shapiro and Patterson (154) studied three groups of subjects; twenty-five highly trained non-smokers (27.5 ± 5.7 years), eleven non-trained healthy non-smokers (20.8 ± 1.8 years) and thirty-one non-trained smokers (28.4 ± 5.7 years). Spirometric tests were performed on all subjects to assess pulmonary capacities and function. These researchers found that athletic training was associated with an increased expired vital capacity and that chronic smoking was associated with a decreased mean maximal breathing capacity. No other significant differences were found.

Chevalier et al. (38) evaluated the effects of cigarette smoking on some of the circulatory and ventilatory responses to exercise of a group of eighteen smokers (mean age 28.9 years) and fourteen non-smokers (mean age 29.7 years). There was no difference between the groups on $\dot{V}O_{2\ max}$ or pulmonary function tests. Smokers exhibited higher resting heart rates ($p < 0.01$) and a tendency toward higher values throughout the exercise period. The recovery heart rates for the smokers were also significantly higher ($p < 0.02$). The oxygen debt of the smokers was considerably greater than that of the non-smokers, and this difference was highly significant ($p < 0.001$). The authors concluded that the differences between the two groups do not appear to be related to ventilatory factors and may, therefore, be due to either circulatory or metabolic differences in the two groups.

Krumholz et al. (101) also found a significantly greater oxygen debt accumulation during exercise in the group of smokers as compared to non-smokers. The smoking group consisted of nine men who had smoked at least one package of cigarettes per day for five years. The nine members of the non-smoking group had never smoked. These authors also found that the smokers had a significantly decreased diffusing capacity at rest and during exercise as well as significantly decreased total lung capacity, inspiratory capacity and vital capacity.

Krumholz et al. (102) in another study, measured the exercise response of ten male subjects (smokers) twenty-five to thirty-three years of age before, after three weeks and after six weeks of abstinence from cigarettes. After three weeks peak ventilation and pulmonary diffusing capacity were significantly increased. As well, the heart rate and oxygen debt produced by five minutes of hard exercise were significantly decreased. After six weeks, the functional residual capacity was reduced and inspiration reserve volume and maximum ventilation volume were increased. Airway resistance was also significantly reduced. The authors concluded that alterations in lung function are present in young smokers and that some of the alterations are quickly reversible with abstinence from smoking.

Zwi, Goldman and Leven (194) tested a group of ten male smokers and ten male non-smokers (21 to 35 years of age) on a battery of cardio-respiratory measures at rest and during exercise. The smoking group in this study exhibited: 1) decreased vital capacity and total lung capacity; 2) greater residual volume; 3) higher pulmonary non-elastic resistance and lower compliance; and 5) lower arterial oxygen saturation during exercise.

"It may be concluded that cigarette smoking impairs pulmonary function and adversely effects the cardiovascular system. The effect is detectable within the first fifteen years after commencing the habit and becomes more obvious with increasing length of smoking history." (194)

Merriman (115) noted a significantly improved exercise tolerance in five subjects after stopping smoking. The author suggests that several changes appear to explain this improvement: 1) reduction in resting heart rate; 2) decrease in heart rate for a given exercise load; 3) decrease in exercise $\dot{V}O_2$ and oxygen debt for the same load; 4) greater work capacity; 5) decrease in $\dot{V}_e$; 6) improved mechanical efficiency of work.

Working with 419 American airmen, Cooper et al. (41) investigated the effects of cigarette smoking on endurance performance. All subjects were tested on the twelve minute walk-run field test of endurance performance and in forty-seven subjects cardio-pulmonary indexes were also obtained during maximal treadmill performance. Subjects were tested at the beginning, after three weeks and after six weeks of basic training. Subjects with a smoking habit showed a consistent impairment in performance at all stages of training when compared to subjects who had never smoked. As well, performance on the twelve minute test was inversely related to the number of cigarettes smoked regardless of the stage of training. The researchers also found that smoking for less than six months did not impair the end-of-training performance, but smoking for longer than six months produced a significant impairment in every category. The only cardio-pulmonary index in which there was a significant difference between smokers and non-smokers during the maximal performance studies was the $\dot{V}_e$ ($p < 0.01$). Maximal oxygen consumption, maximum heart rate and ventilation equivalent were not significantly different. The training response was significantly reduced in those subjects who smoked ten to thirty cigarettes per day.

Peterson and Kelley (134) studied the chronic effects of cigarette smoking upon the acquisition of physical fitness during an interval training program. The subjects for this study were sixty male volunteers who were split into smoking and non-smoking groups based on their smoking habits. The subjects were tested on the Astrand ergometer test for prediction of $\dot{V}O_{2\ max}$ prior to training and after two, four six and eight weeks of interval training. The interval training program required subjects to run a progressively increasing series of 440 yard dashes at an 88 second pace. Pre-training $\dot{V}O_{2\ max}$ values were significantly higher for the non-smoking group, 2.56 litres/minute and 2.33 litres/minute ($p < 0.05$). In most cases the training program was equally effective for the two groups but at the end of the eight weeks the non-smoking group still exhibited a higher predictive $\dot{V}O_{2\ max}$, 2.98 litres/minute to 2.71 litres/minute ($p < 0.01$).

Glassford and Howell (77) studied 277 prospective Edmonton firemen aged 20 to 29 years. The subjects were grouped on the basis of smoking habits into smokers (one hundred ninety) and non-smokers (eighty-seven). All subjects were tested on the Balke-Ware treadmill test. There were no significant differences reported for physical characteristics of the two groups but the non-smokers performed significantly longer on the treadmill test ($p < 0.01$), 16.48 minutes compared to 13.17 minutes, when the data was submitted to t test analysis. Significant differences between non-smokers and moderate and heavy smokers on treadmill test results were also found.

Franks (73) investigated the differences between middle aged smokers (twenty-two) and non-smokers (thirty-six) on selected tests of "physical fitness". He found that non-smokers were better than smokers on breath-holding, vital capacity and resting area under the curve of the brachial pulse wave. There was no statistically significant evidence that the two groups differed on several other measures of resting cardiovascular fitness, cardiovascular response to mental arithmetic or submaximal exercise and recovery.

Though the advice of discontinuing smoking for general health reasons is well founded, the specific effects of smoking on exercise is not totally clear.

Information available on smoking habits of the general population of the United States (106) indicate age and sex differences with men exhibiting a greater percentage of smokers than women and the younger people having a greater percentage than old. Specific age and sex differences indicate:

1) 17 years and up: male 45.9%, female 30.5%
2) 17 to 24 years: male 41.3%, female 29.4%
3) 25 to 44 years: male 54.7%, female 40.2%
4) 45 to 64 years: male 47.3%, female 30.5%
5) 65 years and over: male 24.5%, female 9.5%.

AEROBIC CAPACITY AND BODY COMPOSITION

Checking the "nutritional status" of patients by sight-gauging the thickness of a thumb-forefinger skinfold has been practiced by physicians for well more than a hundred years (27). Information of the constituent make up of the human body is important for the physician in making some diagnosis and then prescribing treatment and for the physical educator and coach in suggesting exercise programs and helping athletes optimize their performance potential. Animal scientists have pursued measurement of body fat in domesticated animals to optimize marketing weights and times. Many of the technical advances have come from researchers in this area.

Until approximately 1890 the estimation of per cent body fat, at least in humans, was a fairly crude procedure. Richer, in 1890, (cited from 27) was the first person to use a caliper to measure the thickness of a double layer of skin and to estimate the amount of fat in a human body based on these measures. Behnke, Feen and Weldham (21) are credited with perfecting the technique of hydrostatic weighing to determine body composition. The use and perfection of many techniques for estimating body composition have been brought forward since that time and practical application of measurements of per cent body fat have become common.

The oldest and most common technique for estimating per cent body fat is the skinfold thickness measurement (1, 19, 27, 28, 31, 37, 45, 59, 67, 82, 98, 130, 135, 153, 160, 168, 170, 184, 193). Various conventions in selection of sites and use of calipers have arisen. The first caliper that gained popular acceptance and use for many years was the Franzen type caliper (74). The main problem with this caliper was the increase in jaw pressure as the jaws were opened. Best in 1954 (24) developed a caliper which alleviated this problem but the production of a caliper for use in the Harpenden growth study in 1955 overshadowed the "Best" caliper. The Harpenden caliper (61,172) meets all of the criterion for skinfold calipers set forward by Tanner and Whitehouse (172) and the use of the Harpenden calipers is recommended. Other calipers have been produced (Lange caliper) to these specifications and are commonly used as well.

Measurement of specific gravity of the human body by the hydrostatic (water displacement) method is considered more reliable and accurate than the skinfold measures technique (23). This method is the second most common technique and has often been used to validate equations set up for skinfold measures (1, 21, 28, 30, 33, 58, 98, 126, 137, 193).

Another technique which has become popular is the measurement of potassium (K^{40}) in the body with a scintillation or whole body counter (19, 45, 68, 117, 170). This technique is based on the principle that the amount of measureable K^{40} in fat is negligible so that the measured K^{40} in a body is directly related to the lean body mass (68).

Other less well known techniques have been developed and used successfully in specific applications: ultrasonic measurements (26, 171), X-ray measurement (171), fat soluble gas absorption (105), and air displacement method (66).

As previously stated, a number of conventions in sites and predictive equations have arisen through the widespread use of skinfold measures in estimating per cent body fat. A recommendation of the Committee on Nutritional Anthropometry of the Food and Nutrition Board, National Research Council, U.S.A., 1956, (cited from 193) was that standard sites be used in the estimation of body fat: 1) chin; 2) subscapular; 3) chest, 3 sites; 4) waist; 5) abdomen; 6) suprailiac; 7) triceps; 8) thigh; and 9) knee. The above committee (cited from 31), however, specified two areas as being particularily useful for measuring the thickness of skinfolds: upper arm (triceps) and the subscapular area of the back. Many studies, however, have utilized a large number of sites (1, 28, 37, 67, 98, 130, 153, 184).

Brozek et al. (31) suggest that skinfold measures are ideally suited for nutritional surveys and also state that the method is finding increasing use in the quantitative appraisal of leanness-fatness in medical practice and clinical and laboratory research. Some researchers including Brozek et al. (31), Crook et al. (45), Brozek (27), Seltzer et al. (153) have found that the estimates from fewer sites was less time consuming and in many cases as accurate or more accurate than the twelve or thirteen sites sometimes used.

Seltzer et al. (153) utilized five sites (triceps, thigh, subscapular, knee and abdominal) and concluded that of the five skinfold taken, the triceps appeared to be the best predictor of body density in obese adolescent girls. The correlation between body density (from under water weighing) and the triceps measure was r=.795 which was significant. The authors also developed a regression equation for predicting body density from a triceps skinfold measure.

Durnin and Rahaman (59) measured four sites on their subjects (biceps, triceps, subscapular and suprailiac) and developed a regression equation that was capable of predicting per cent body fat with an error of about ±3.5%.

Sloan and Weir (168) developed a nomogram for estimating per cent body fat from thigh and subscapular folds for men and suprailiac and triceps folds for women.

The International Biological Program (I.B.P.) recommended that the internationally accepted sites (165) for skinfold measures should be the triceps, subscapular and suprailiac. This group suggested that the use of the triceps measure singly should be used with caution. The committee of I.B.P. which studied this matter also concluded that there did not appear to be justification for logarithmic transformation of skinfold measures and that superior accuracy could be gained by using the measures in millimeters of skinfold measured.

A combination of two sites was found useful by Barter and Forbes (19). The biceps and triceps measures were the best of several anthropometric measures for predicting total body fat. The correlation of the average biceps and triceps and total body fat for men was $r=.58$ ($p< 0.01$) and for women $r=.43$ ($p< 0.01$).

Crook et al. (45) and Chen et al. (37) found that a combination of subscapular and triceps measures were the best estimators of per cent body fat. Chen et al. (37) concluded that if fewer skinfolds are desired as in clinical or field work, the standard triceps and subscapular sites are optimum.

"The practical conclusion from the attempt to predict specific gravity and from body measurements is that triceps and subscapular skinfolds did almost as well as a battery of thirteen skinfolds and much better than an extensive anthropometric battery." (37)

The Committee on National Anthropometry of the Food and Nutrition Board, U.S. National Research Council (cited from 31) specified two areas as particularly useful for measuring the thickness of skinfold for large groups: the upper arm (triceps) and the subscapular area of the back. Brozek et al. (31) go somewhat further in suggesting that in some studies it is advantageous to measure only upper arm skinfold and that this is especially true when women as well as men are studied. In another paper, Brozek (27) suggests that the selection of sites involves several considerations: 1) accessibility; 2) precision in locating the site; 3) relative homogeneity; and 4) validity as an index of total fat.

"Considering all criteria in terms of which sites must be judged, the first prize goes unquestionably to the triceps skinfold." (27)

Pett and Ogilvie (135) in the "Canadian Height-Weight Survey" utilized the single triceps skinfold measure to estimate per cent body fat for the above reasons. The norms provided by this study will be considered later.

Heald et al. (82) refers to the triceps skinfold as providing a practical and accurate estimate of adiposity in adolescent boys.

Keys and Brozek (98) provide reliability data for triceps skinfold measurements on eighty-three persons by two observers, r=.916. These authors also quote Tanner's reliability measures for the measurement of triceps skinfold as r=.982. Keys and Brozek report a correlation of r=-.649 between specific gravity and absolute value of triceps skinfolds. Keys and Brozek are in agreement with Shephard et al. (165) in suggesting that the absolute value of the skinfold is the best way to express the skinfold measurement.

Brozek and Keys (28) in another article report correlations of r=-.828 for younger men and r=-.647 for older men between triceps skinfold and specific gravity. Steinkamp et al. (170) report a correlation between triceps and kilograms of body fat of r=.707 for younger men and r=.798 for younger women. The correlation for all groups was r=.586. All correlations were significant. These authors (170) conclude that predicting body composition from skinfolds is a useful tool.

Thus while there is some controversy about the use of the triceps skinfold as a single measure of body fat there is much to recommend its use when dealing with a large group of people.

There is much evidence that one of the effects of hard physical training is a reduction in body fat with corresponding increase in lean body mass. Body weight normally decreases at the start of training and then levels off and increases as increments in active tissue occur (15, 54, 93, 131, 187, 188). As well studies of active versus sedentary individuals also show the active individual with a smaller percentage of body fat (2, 29, 79, 149).

Brozek et al. (31) also found lower per cent body fat in persons whose occupational physical activity level was higher. Greene (78) studying 350 overweight patients found that the onset of obesity could be traced to simultaneous sudden decrease in activity level in 67.5% of the patients. An increase in food intake, on the other hand, could only be obtained in 3.2 % of the cases.

Chirico and Stunkard (39) measured the physical activity of 15 obese women and 25 obese men and compared their results with the activity levels of matched controls. Obese subjects were significantly less active than non-obese subjects. Obese women walked an average of 2.0 miles per day as compared with 4.9 miles per day for the non-obese. Obese men walked 3.7 miles per day compared with 6.0 miles per day for the non-obese males. Rank order analysis revealed that the difference between obese and non-obese subjects was considerably greater among women than men.

"While below average muscular activity on the part of the obese is a matter of popular and immemorial record, there is a physiological basis for reassessing the possibity that inactivity plays a primary role in the etiology of this disorder." (114)

Conventionally $\dot{V}O_{2\ max}$ when used to express the functional capacity of the organism is expressed as a function of body weight. Buskirk and Taylor (33) suggest that when $\dot{V}O_{2\ max}$ is being used to examine the capacity to perform exhausting work, the values should be expressed as $\dot{V}O_2$/kg of body weight/minute. They go on to say that when $\dot{V}O_{2\ max}$ is being used to examine the performance of the cardio-respiratory system, the values should be expressed as $\dot{V}O_2$ /kg fat free body weight/minute.

When aerobic capacity is expressed as $\dot{V}O_2$/kg body weight/minute, an individual with greater than optimal amount of body fat is at a disadvantage and this is as it should be since his capacity to perform work is limited by the mass that he must move. As well, the ratio of tissue engaged in energy production is greater in the individual with a lower per cent body fat, resulting in a greater capacity per unit of body weight.

Body composition varies with age and sex. The results of studies of per cent body fat changes with age in males and females do not show an extremely high degree of conformity. One of the most comprehensive studies of per cent body fat in both sexes and over a wide range of ages is that of Parizkova (131). In this study a total of 1460 subjects ranging in age from newborn infants to 60 years were measured for skinfold thickness at 10 sites. Per cent body fat, according to Parizkova's results, is at a minimum at very early ages with rapid increases in subcutaneous fat up to approximately three years of age when a levelling off process occurs. In all cases, the female exhibits a greater per cent fat than the male. At approximately the age of 8 years the female begins to increase body fat quite rapidly. The male begins to increase about nine or ten years but levels off again at about eleven or twelve until about 15 years when another body fat increase occurs. The sex differences in per cent body fat are most marked after puberty; in maturity they continue to be significant as regards the trunk (abdominal and hips) as well as the extremities. At age sixty, the sex differences persist as at age thirty. Age and sex variations in body density mirror body fat changes. The male always exhibits a significantly higher density than the female and the greatest variation occurs at about 15 to 17 years of age when the female is immediately post-pubescent and the male has reached a plateau in terms of increasing body fat. Parizkova (131) observed a strong correlation between the proportion of lean body mass and various functional tests such as oxygen consumption during moderate exertion and $\dot{V}O_{2\ max}$ both in young and old individuals.

Pett and Ogilvie (135) in a height-weight survey of Canadians also measured the triceps skinfold of 22,000 individuals from two years of age up. This data revealed that, similar to Parizkova, the female at all ages exhibited a greater skinfold and that the female shows a rapid and maintained increase in fat from approximately nine or ten years with a large increase at about 15 to 16 years. The male results are not similar to Parizkova's, showing a decrease from age two to about nine years when there is an increase for about a five year period. Another decrease occurs during the years 15 to 23 or 24 and then a gradual increase to approximately 60 years when the triceps measure again decreases.

Norris et al. (126) utilized a measurement of body density to estimate per cent body fat in 143 male adults, 20 to 99 years. Calculating per cent body fat by their own formula, these authors' data shows a consistent decrease in per cent body fat from the 20 to 29 year age group to the 50 to 59 year group when a slight increase was noted and then a continual decrease to the 80 to 89 year age group. When the equations for per cent body fat of Brozek and Keys and Siri are used the per cent body fats show some variations. The 20 to 29 year group are lower in body fat and there is an increase during the 40 to 49, 50 to 59 and 60 to 69 year groups and then a decrease. The data from this study conforms somewhat to the Pett and Ogilvie data.

Brozek et al. (31) concluded that middle aged male railroad employees showed negligible and inconsistent age trends in skinfold thickness. The age range that these researchers measured were from approximately 40 to 55 years.

Young et al. (193) estimated the per cent body fat of 94 women 16 to 30 years of age and 88 women 30 to 70 years of age. The results of this study show a marked similarity in per cent fat of the groups 16 to 30 years and 30 to 40 years (28.7% and 28.75%). The next three age groups exhibit a continual increase in per cent body fat, 40 to 50 years: 35.3%; 50 to 60 years: 41.8%; and 60 to 70 years: 44.6%. The estimates in this study were based on skinfold measures which included triceps measures. The triceps measures for the age groups are 16 to 30 years: 25.4 mm; 30 to 40 years: 23.6 mm; 40 to 50 years: 30.0 mm; 50 to 60 years: 29.3 mm; and 60 to 70 years: 28.02 mm. The triceps alone do not follow the per cent of body fat estimated from the total of twelve measures taken.

Wessel et al. (184) also used skinfold measures for women aged 20 to 69 years to estimate per cent body fat. "It is evident that aging in women is accompanied by an increase in the skinfold thickness as well as the pattern of distribution." An increase was noted in the thirties (lower ribs, waist, arm and scapula sites), fifties (abdominal-pubis and umbilicus, waist and upper arm) and decreased during the sixties. In this study the single triceps measure tended to be a very accurate assessment of the per cent body fat estimated from six sites.

Even with the variation observed in data, some generalizations appear to be reasonable. The female always exhibits a greater per cent body fat and the major part of this difference begins at puberty. From age twenty to sixty both males and females tend to increase body fat. Post sixty years there does not appear to be agreement but suggestions that at least in males a slight decrease in body fat may be observed.

CHAPTER III

METHODS AND PROCEDURES

THE SAMPLE

A total of 1544 subjects representing a broad cross-section of the Sasktoon community, including 845 female and 699 male participants ranging in age from 14 to 74 years made up the original sample. Of the above number a total of 1230 men and women were included in the test data that was used in this study. Figure 1 illustrates the age and sex distribution of this sample.

Participation in the study was strictly voluntary. Initially 2648 people were contacted after random selection from the Saskatoon telephone directory. Of the people contacted in this method 899 or 34% agreed to participate in the study and were accepted; 61% were either not interested or unable to participate because of other commitments Subjects were screened over the telephone if they agreed to participate, using the following questions: 1) Have you ever had heart trouble? 2) Have you or do you now have persistent chest pains? If the answer to either of the above questions was positive, the persons were rejected as subjects. Five per cent were rejected for this reason. If the answer to both questions was negative the subjects were scheduled

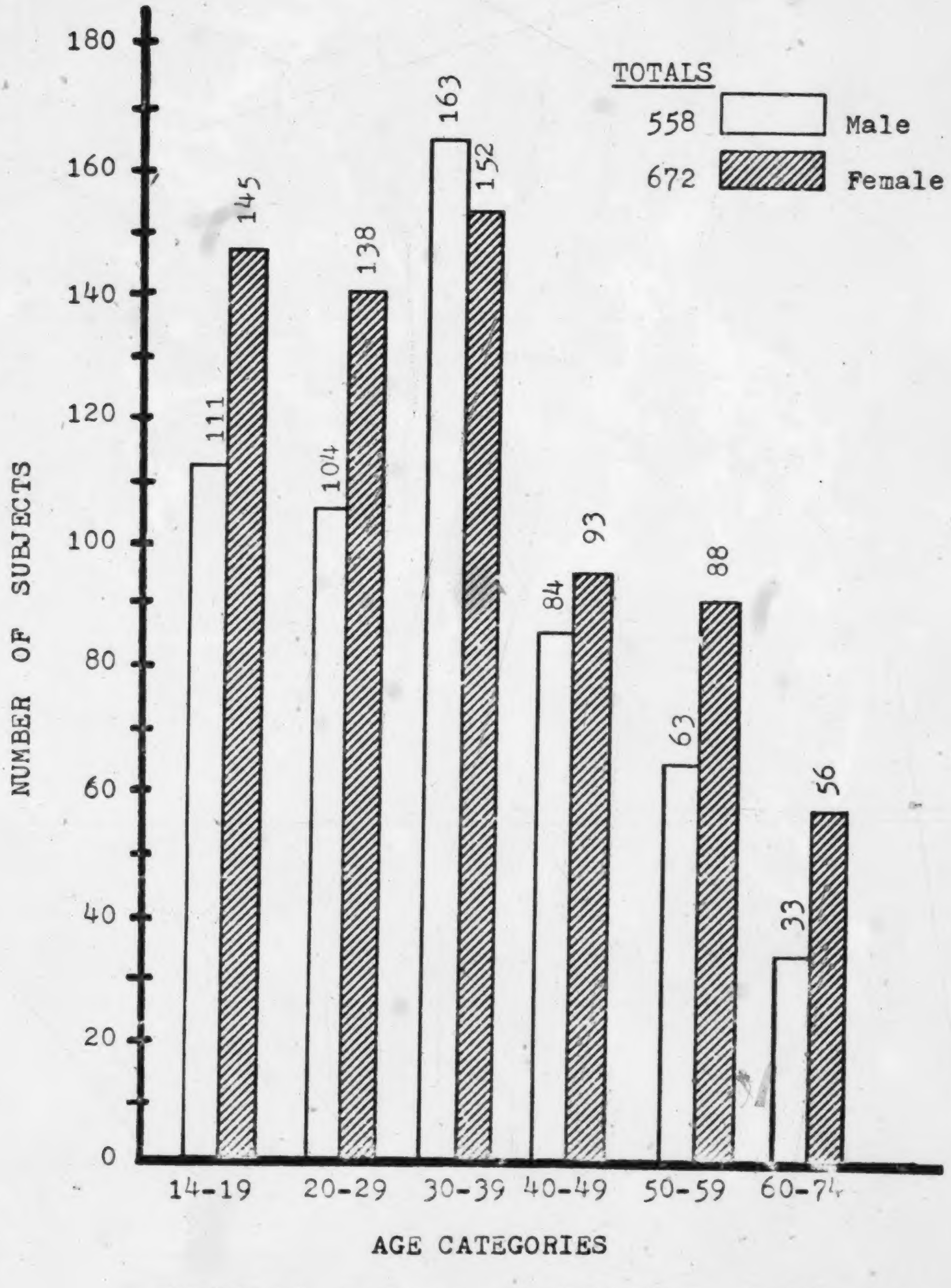


FIGURE 1: Frequency Distribution of Male and Female Subjects

for testing. Of the 899 persons who agreed to come to be tested, 850 (95%) actually appeared to be tested. A further 72 of these subjects were eliminated by yet another medical screening (Appendix A) prior to initial exercise testing (step test) and another 8% were eliminated prior to testing or shortly after commencing testing due to abnormal resting or exercise E.C.G.trace. Thus 713 of the telephone volunteer group went on to the Astrand Ergometer test and of these, final results were obtained on 686 men and women. The 27 persons disqualified at this stage were for abnormal resting or exercise E.C.G. traces. The remaining 544 subjects that make up the data were volunteers who came forward after media campaigns to solicit assistance. Most of the subjects in the 14 to 19 year age range were students from two local high schools, Bedford Road Collegiate and Evan Hardy Collegiate.

DESCRIPTION OF TEST ITEMS AND QUESTIONNAIRE

Aerobic Capacity

Aerobic capacity of the subjects was predicted on the basis of a submaximal exercise test as described by Astrand (11) and utilization of the Astrand-Ryhming nomogram (13). Subjects exercised at a submaximal level on the bicycle ergometer for six minutes or until a steady state submaximal heart rate was attained. The work load was determined through the combination of pedal resistance and pedal r.p.m.'s. Heart rate was monitored continuously (through digital display outputs) and recorded during the last ten seconds of each minute. The individual work loads were initially set by the test administrator after consulting the step test results. To provide added insurance that the load was neither too high nor too low to result in a heart rate in the desired range, work load was adjusted after the first minute of exercise if necessary. This variation of the usual test procedure for the Astrand ergometer test was approved by the originator, Dr. P. O. Astrand, as a worthwhile modification that would not bias the final results. If the working heart rate during the fifth and sixth minutes of the test were within five beats and over the criterion level, the subject had completed the test. If the heart rate had not reached the criterion level after six minutes, the work load was increased and the exercise continued until a steady state was achieved. The subject also continued exercising after the initial six minutes if his heart rate had not reached a steady state (5 beat criterion), until this condition was met or for another three minutes. Subjects were not allowed to start the test with a heart rate in excess of 100 beats/minute.

The pedaling frequency was maintained by the use of a metronome beating at 100 beats/minute so that one revolution of the pedals was accomplished with each two beats. The test administrator was responsible for the subject maintaining the cadence and if a subject was unable to do so the test was terminated. Prediction of maximal oxygen consumption was made from the Astrand-Ryhming nomogram by use of a modified computer program as set out by Shephard (162).

Skinfold Measurement

The skinfold measure was taken with the subject standing erect and relaxed. All measures were taken on the right arm hanging in a vertical position. A vertical skinfold was lifted and measured over the midpoint of the triceps muscle belly, midway between the olecrannon and the tip of the acromion process. A single technician who was well trained in the technique was responsible for all measurements. One measure was taken and recorded. The same Harpenden calipers (172) were used for all measures.

Physical Activity Self-Rating

A self-rating questionnaire item (Appendix B) was used to measure each subject's physical activity level for the immediate preceding three months. The subject was asked to signify which of the five categories in the item most accurately described his or her physical activity over the period of the last three months. For the purpose of analysis the first two categories were combined (A. no deliberate activity to improve physical fitness and B. occasional moderate activity) to form the low activity group. The third category (C. regular moderate activity) was retained as the moderate activity group and the last two groups (D. very frequent and E. regular training) were combined to form the high activity group.

Smoking Habits

Subjects were asked to describe their current smoking habits in question three of the questionnaire included as Appendix B. The subjects who indicated choices A or B (I have never smoked or I have given up smoking) were classified as non-smokers for the purposes of the study and were given a numerical rating of 10. Subjects who indicated C or D (I smoke cigarettes or I smoke a pipe or cigar) were classed as smokers and assigned a numerical rating of 20. The limitations of this simplified system of rating smoking habits is recognized but without a superior system of quantification readily available these limitations were accepted.

EQUIPMENT AND CALIBRATION

All equipment used in the study was leased from Quinton Instruments of Canada expressly for this project so that all equipment was new. A highly qualified electronics technician employed by Quinton was present during all testing sessions and was responsible for calibration and maintenance of all equipment.

High quality electrocardiograms and accurate heart rate determinations were made on subjects exercising on Monark Bicycle ergometers. The equipment allowed continuous display of exercise E.C.G.'s on two eight channel systems capable of monitoring sixteen subjects simultaneously. Digital display of heart rate, a push button selection of recording any one of the E.C.G. traces and visual display of all traces on oscilloscopes were features of the monitoring equipment. The components were manufactured by Mennen-Greatbach Co. Ltd. and assembled in Toronto by Quinton specifically for the project.

Starting with patient electrode contact care was taken in the selection of high quality silver-silver chloride disposable electrodes with hypoallergenic micropore tape adhesive. These electrodes exhibited low polarization potentials and were applied after removal of the top layer of skin with biobrade adhesive. The patient cables were manufactured specifically for this study, of highly flexible, shielded cables with provision for simple application to the electrodes to allow minimal patient application time.

The signal amplifiers were situated close to the subjects and connected to the main console with a single umbilical cord. These amplifiers were selected to feature very high patient isolation to eliminate any possibility of electrical hazard to the patient, as well as offering high stability and filtering to provide stable E.C.G. tracings.

The central console featured an eight trace oscilloscope with a "push to locate" feature. The control technician could depress a button for each subject which would blank out all the other seven confusing traces and leave only the selected tracing on the oscilloscope. Digital heart rate meters using 3/8 inch light emmitting diode displays indicated accurately ($<$150 beats/minute ± 1%, $>$ 150 beats/minute ± 2%) the instantaneous heart rate of the subject being tested. The instrument operated on an average of ten beats extrapolated to minute values and updated on a beat to beat basis. These readings could be frozen for recording by a single switch. Additionally, a push button selector for any of the eight subjects automatically activated a recorder which recorded the selected E.C.G. wave form for a preset adjustable period, and then shut off automatically.

Provision was made for cardiac emergency by the presence of a multi-lead electrocardiogram, oxygen resuscitator and a D.C. defibrillator. This equipment was set up in an enclosed emergency area within the testing area. Drugs and the appropriate medical instruments were also available in this area.

The eighteen Monark bicycle ergometers were calibrated daily by the technician and care was taken to maintain the accuracy of the calibration in their use. Two extra ergometers were always available in the event of maintenance problems.

The heart rate monitoring equipment was checked and calibrated daily as well so that the accuracy [illegible] the digitally displayed heart rates was maintained within the prescribed error range (± 1% up to 150 beats/minute, ± 2% over 150 beats/minute).

Scales used to measure body weight were leased from Toledo Scale Co. and were calibrated and adjusted prior to their use.

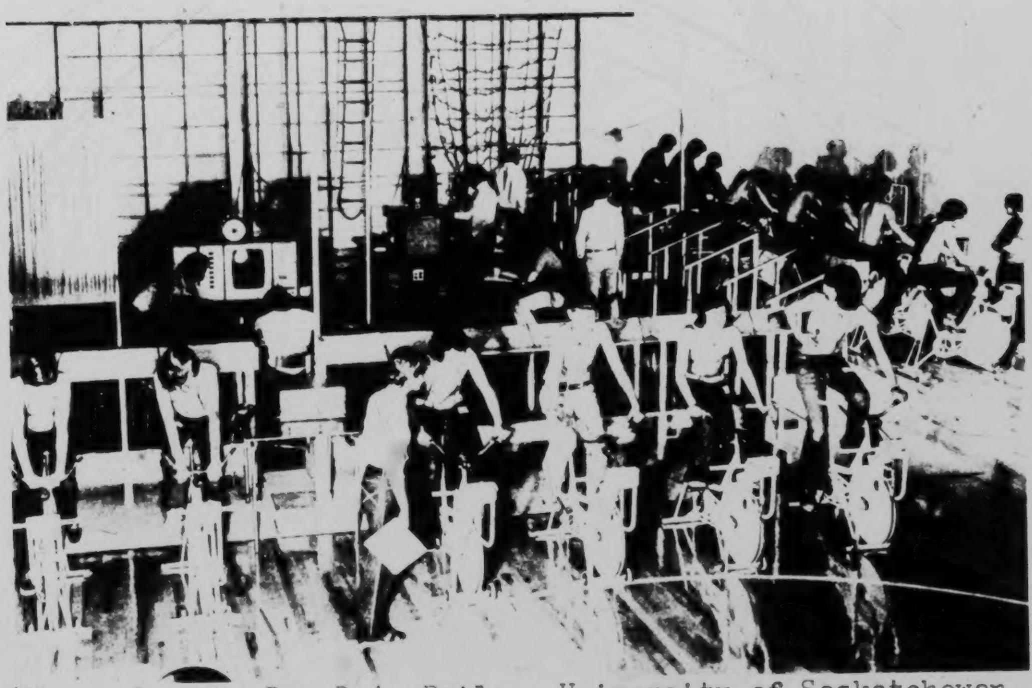
TESTING SITES

Four testing sites were utilized in the collection of the data. The main testing site was located in the Education Building on the University of Saskatchewan campus. The main testing room used was a small gymnasium with an adjacent large classroom and hallway utilized for anthropometric and strength measures, application of electrodes and registering and completing questionnaires. Plate 1 shows the main testing area. This site was used for evening and week-end testing. One eight subject testing unit was maintained at this station on a permanent basis.

A mobile test station was set up for shorter periods of time in three different locations. The first outside test center was set up at Bedford Road Collegiate utilizing two adjacent classrooms with a connecting anteroom. The mobile test center utilized a second eight subject monitoring unit that was virtually the same as the stationary unit except for some features which made it easier to move.

The second mobile station was set up after leaving Bedford Road Collegiate, at the Saskatchewan Institute of Applied Arts and Science, with the third location being a downtown office building. A large section of the main floor of Federated Cooperatives office building was converted to a testing station for the time required to complete testing of volunteers who wished to be tested in this location.

The bulk of the subjects who were contacted via the random phoning program were tested at the University while



(Photo Couresy Dr. D.A. Bailey, University of Saskatchewan, Saskatoon)

PLATE 1: The Main Testing Area Showing Sixteen Subjects Being Tested Simultaneously

the majority of the persons tested at the second and third mobile testing stations were volunteers recruited by other means.

TESTING PROCEDURES

Upon arrival at the test center, subjects were asked to complete a medical questionnaire (Appendix A) and an activity-smoking questionnaire (Appendix B). Subjects were assigned a subject number at this time and a sticker with the subject's first name and subject number was applied to the subject's clothing. This insured that the data collected would be recorded under the correct subject number.

The following step in the test procedure was the measurement of height, weight, triceps skinfold and grip strength. The data from these measurements was recorded beside the subject number and the subject moved on to the next area which involved the application of the E.C.G. electrodes.

The skin surface on which the electrodes were to be attached was abraded and the disposable, pregelled electrodes were placed on the subjects, (CM_5 lead placement). The subjects then advanced to the exercise test area.

On the first visit to the test center, subjects were tested on the step test designed as the Canadian Home Test of Fitness. After completion of this test, subjects were familiarized briefly with the bicycle ergometer and rescheduled for the Astrand bicycle ergometer test. Upon arrival at the test center for the second exercise test (bicycle ergometer test), subjects were required to complete another simple medical screening questionnaire and then prepared for the exercise test by having electrodes attached.

The subjects were, in most cases, tested in groups of eight or sixteen, depending on the number of test units available and the number of subjects scheduled. Subjects were scheduled by age group and sex to facilitate the testing procedure. Upon arrival at the exercise test area, subjects were familiarized briefly with the test by individual test admininistrators and the bicycle ergometer was adjusted to suit the size of the subject (11). The E.C.G. cables were then attached to the electrodes and the recording was checked and noted by the coronary care nurse. The initial selection of the load was made by the individual test administrator upon consideration of the subject's age, sex, size and performance on the stepping test which had been completed at least two days previously. After all E.C.G. traces were cleared by the coronary care nurse, the subjects were given specific instructions for the test by the supervisor. The metronome was then started and all subjects commenced the test. Each individual test administrator was responsible for a maximum of three subjects. Their responsibilities included checking the loads on the ergocycles each minute and changing then if required after the first minute of exercise. The test administrator was also responsible for checking each subject's cadence so that they maintained the 50 rpm required. As well, the test administrator recorded subject number, station number and work load which was transferred to the recorder sitting in front of the digital display monitor.

The decisions on raising or lowering work loads or terminating a subject due to excessively high heart rate was the responsibility of the control technician through consultation with the test supervisor. The coronary care nurse and the attending physician were responsible for terminating exercise for any subject who exhibited any medical contraindication to the exercise test.

At the fifty second mark of each minute during the exercise test the heart rate display was "frozen" to allow recording of the heart rate. This data was recorded by two technicians for each eight subject unit. They also recorded the information gathered by test administrators at the end of the test.

At the completion of the test subjects were unhooked from the cables and informed of the time they could expect the test results and information to be sent to them.

The test team was composed of highly qualified and competent personnel in each of the required areas. Personnel were also selected on their ability to communicate with subjects and to be able to make them as comfortable as possible in the testing environment. The informality was also carried over into the attire of the testing team, none of whom wore "clinical" clothing. From the time the subject entered the building an effort to provide a friendly and informative atmosphere was maintained. At each step of the process the subjects were informed of exactly what was being done, why, its importance and what they could expect at the next station. The educational opportunity that was present in this situation was maximized as well as attempting to alleviate any anxieties that might be present.

Competent medical personnel were available at all testing sessions and provision was made to handle any emergencies that might possibly arise.

DATA HANDLING

All subjects were assigned a subject number upon registration and a sticker bearing this number was placed on their clothing. Data was recorded using only this number to differentiate subjects.

The questionnaires (medical and activity) were also coded with the subject number and, thereafter, data was transferred with the subject number as a reference.

Anthropometric-strength data were recorded on a special sheet designed for that purpose (Appendix C) with care taken to record individual data with the correct subject number.

The test administrators in the exercise test also recorded their data on a special sheet (Appendix D). The test administrator also recorded the reason for test termination by the use of a code developed specifically for this purpose (Appendix E).

The control monitor recorder recorded the working heart rate for the subjects directly onto a computer data coding form (Appendix F) from which the data was key punched. Before the next group of subjects were tested the data gathered by the test administrator was recorded on the data coding form as well.

At the end of each testing session, a comprehensive check of all data was made and then prepared for coding and key punching. Data was stored on computer tape after key punching.

DATA ANALYSIS

Selection and Substantiation of High and Low Aerobic Capacity Groups

The data for male and female subjects was split by sex into twelve groups; that is, six age categories were created for each sex. The age groupings were 14 to 19 years (age group 1), 20 to 29 years (age group 2), 30 to 39 years (age group 3), 40 to 49 years (age group 4), 50 to 59 years (age group 5) and 60 to 74 years (age group 6). Within each of the twelve age and sex groups the subjects were further divided into high, medium and low aerobic capacity groups by placing one third of the subjects with the highest predicted $\dot{V}O_{2\ max}$ in the high aerobic capacity group, the middle one third of subjects on $\dot{V}O_{2\ max}$ in the medium group and the remaining lowest one third of subjects into the low aerobic capacity group. For the purposes of this study only the high and low aerobic capacity groups were studied so the medium group data was for all purposes ignored.

The criterion for extreme groups was chosen to allow a sufficient number of subjects in each group and yet still retain the required aspects of extreme groups. To determine whether or not the groups were significantly different in predicted $\dot{V}O_{2\ max}$, a two way analysis of variance was performed on the data. The null hypothesis of no difference between the high and low aerobic capacity groups was tested using $\alpha = .05$ for significance. Scheffé contrasts were set up and calculated to allow significance testing of the individual group means.

Multivariate Analysis Within Age Groups

To test the null hypothesis of no difference between the high and low aerobic capacity groups on the three discriminant variables, a two sample Hotellings' T^2 test was employed. Hotellings' T^2 statistic allows the testing of significance of the difference between vectors of means. In the present case the centroids of the three factors for the high and low capacity groups made up the vectors to be tested. The null hypothesis that was tested was that on the average, high and low capacity groups did not differ in their centroids on the three discriminant factors (173).

$$Ho : \mu_1 - \mu_2 = \begin{bmatrix} \mu_{11} - \mu_{12} \\ \mu_{21} - \mu_{22} \\ \mu_{31} - \mu_{32} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

Test data for each of the six age groups (14 - 19, 20 - 29, 30 - 39, 40 - 49, 50 - 59, 60 - 74) and for each sex was subjected to this statistical analysis. In all cases the α level required for significance was $\alpha = .05$.

To provide further information on the individual variables within each age and sex group, contrasts were set up to determine exactly which of the variables were significantly different. The α level required for significance was $\alpha = .05$.

To provide insight into the relationships between the three variables and how they act to place a person into the high or low performance group, linear discriminant function analysis was utilized. The relative weightings of each of the three factors in question allowed observations as to their influence in the difference between high and low aerobic capacity group.

$$Y = a X_1 + b X_2 + c X_3 \qquad (123)$$

where X_1 = physical activity level

X_2 = smoking habits

X_3 = fatness

Multivariate Analysis Between Age Groups

A two way multivariate analysis of variance for a fixed effects model with unequal observations per cell after the method described by Morrison (123) was employed to test the null hypothesis of no difference between the six age groups and capacity groups on the three discriminant variables. This analysis was carried out on both male and female data separately using the model in Table I.

TABLE I

6 x 2 Multivariate Analysis of Variance With Fixed Effects and Unequal Observations Per Cell

	AEROBIC CAPACITY	
Age	High Capacity	Low Capacity
14 - 19	$X_{111}, X_{211}, X_{311}$	$X_{121}, X_{221}, X_{321}$
20 - 29	$X_{112}, X_{212}, X_{312}$	$X_{122}, X_{222}, X_{322}$
30 - 39	$X_{113}, X_{213}, X_{313}$	$X_{123}, X_{223}, X_{323}$
40 - 49	$X_{114}, X_{214}, X_{314}$	$X_{124}, X_{224}, X_{324}$
50 - 59	$X_{115}, X_{215}, X_{315}$	$X_{125}, X_{225}, X_{325}$
60 - 74	$X_{116}, X_{216}, X_{316}$	$X_{126}, X_{226}, X_{326}$

Table I where X_{abc} represents: a - variable (1,2,3)
b - capacity (1,2)
c - age group (1,2,3,4,5,6)

To provide further information on the individual variables between age groups and capacity groups, contrasts were set up to determine exactly which of the variables were significantly different.

The linear discriminant functions calculated in the "within age group" analysis were now considered in terms of the different weightings observed between age groups.

$$Y_{\substack{14-19 \\ \text{male}}} = a_{11} X_1 + b_{11} X_2 + c_{11} X_3$$

$$Y_{\substack{20-29 \\ \text{male}}} = a_{12} X_1 + b_{12} X_2 + c_{12} X_3$$

where X_1 - physical ability

X_2 - smoking habits

X_3 - fatness

and where a_{ij} has i - capacity group

j - age group

Since the differences in weights cannot be subjected to significance testing only observations as to similarities and dissimilarities will be allowed.

Male-Female Aerobic Capacity Groups

To determine whether or not the male-female high aerobic capacity groups in the same age categories were significantly different as well as the male-female low aerobic capacity groups in the same age categories, a two way analysis of variance as described by Winer (189) was performed on the data. The null hypothesis of no difference between males and females in aerobic capacity was thus tested using the significance level $\alpha = .05$. Scheffé contrasts were set up and calculated to allow significance testing of individual group means.

Multivariate Analysis Between Male-Female Groups

A two sample Hotellings' T^2 test was employed to test the null hypothesis of no difference between male and female subjects in each of the age groups for high capacity and low capacity subjects on the three discriminant variables. The α level required for significance was $\alpha = .05$. Again, to provide further information on the individual variables within each age and capacity group, contrasts were set up to determine exactly which of the variables were significantly different. The α level required for significance was again $\alpha = .05$.

Linear discriminant function analysis was again employed on this data to provide information on the relationships between the three variables as they act to differentiate male and female subjects.

All statistical analysis were completed utilizing the IBM 360 computer and programs developed and documented by the Division of Educational Research Services. Some of the analysis was done at the University of Saskatchewan Computer Center with the balance being completed at the University of Alberta Computer Center.

All of the statistical methods utilized are parametric. The decision to use parametric statistics came after consultation with a University of Alberta statistician, T.O. Maguire, 1974, and reading the excellent review of parametric versus non-parametric statistics for ordinal data by Orlick (129). His conclusion supported the use of parametric statistics with ordinal (scaled) data.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS

PHYSICAL CHARACTERISTICS OF THE SUBJECTS

Tables II and III contain the age, height and weight data for the female and male subjects considered in this study. The male and female subjects for whom complete questionnaires were not obtained were not included in the study, so that unequal subgroup numbers resulted.

It may be noted that for males the high aerobic capacity group in each of the first four age categories (14 to 49 years) exhibited a lower mean body weight and shorter mean height than their low aerobic capacity counterparts. In the 50 to 59 and 60 to 74 year age groups the high aerobic capacity group were, on the average, lighter and taller than the subjects who fell into the low aerobic capacity classification. The subjects who were classified as low aerobic capacity were, on the average, slightly older than the high capacity group. The one group that was an exception was the 30 to 39 year group in which the high capacity group had a mean age of 33.3 years and the low capacity group 33.2 years.

TABLE II

Physical Characteristics of Female Subjects Aged 14 to 74, By Age Group and Aerobic Capacity Group

Age Group	Capacity Group	N	Height (cm)	Weight (kg)	Age (yrs)
14 - 19	High	33	163.50	55.67	15.5
	Low	41	161.54	59.22	16.0
	Mean		162.52	57.45	15.75
20 - 29	High	40	162.46	56.37	22.9
	Low	43	161.62	58.09	24.6
	Mean		162.04	57.23	23.75
30 - 39	High	46	163.81	58.19	32.8
	Low	49	162.13	63.97	34.8
	Mean		162.97	61.08	33.8
40 - 49	High	27	162.86	61.07	43.5
	Low	29	159.07	61.60	45.4
	Mean		160.97	61.34	44.45
50 - 59	High	27	160.92	61.51	52.9
	Low	26	160.92	64.99	54.3
	Mean		160.92	63.25	53.6
60 - 74	High	15	159.74	59.97	63.4
	Low	19	160.60	63.07	63.9
	Mean		160.17	61.52	63.65

TABLE III

Physical Characteristics of Male Subjects Aged 14 to 74, By Age Group and Aerobic Capacity Group

Age Group	Capacity Group	N	Height (cm)	Weight (kg)	Age (yrs)
14 - 19	High	24	173.31	63.12	15.1
	Low	26	174.79	69.27	15.5
	Mean		174.05	66.20	15.3
20 - 29	High	28	175.09	74.21	24.5
	Low	33	177.47	80.82	25.8
	Mean		176.28	77.52	25.15
30 - 39	High	49	175.89	74.49	33.3
	Low	49	176.74	83.79	33.2
	Mean		176.32	79.14	33.25
40 - 49	High	25	176.16	77.44	43.8
	Low	27	176.37	86.54	44.6
	Mean		176.27	81.99	44.2
50 - 59	High	20	173.98	76.57	53.4
	Low	19	170.91	79.33	54.2
	Mean		172.45	77.95	53.8
60 - 74	High	10	171.44	74.44	62.5
	Low	11	170.11	78.16	65.6
	Mean		170.78	76.30	64.05

Female subjects in the high capacity group, like the males, had a lower mean weight than the low capacity group but unlike the males, the high capacity group was also consistently taller than their low capacity counterparts. The females in the high aerobic capacity group were also consistently younger than the low capacity group, similar in this respect to the male subjects.

PREDICTED $\dot{V}O_{2\ max}$ MEAN VALUES

Table IV contains the mean predicted $\dot{V}O_{2\ max}$ (ml/kg/min) values for male and female subjects, high and low aerobic capacity groups for each age classification

The overall mean (14 to 74 years) for males in the high aerobic capacity group was 38.29 ml/kg/min and for the low capacity group 24.58 ml/kg/min. Female mean values were 33.39 ml/kg/min and 19.10 ml/kg/min for the high and low capacity groups respectively.

SUBSTANTIATION OF HIGH AND LOW AEROBIC CAPACITY GROUPS BY ANALYSIS OF VARIANCE

A two way analysis of variance was run on the male and female data to determine if the high and low aerobic capacity groups were in fact significantly different.

The analysis of male data revealed significant F values at $p < 0.01$ for both A and B main effects and AB (age x capacity) interaction. Thus, the null hypothesis of no difference between the aerobic capacity of the high

TABLE IV

Predicted $\dot{V}O_{2\ max}$ Mean Values and Standard Deviations for Male and Female Subjects

Age Group	Capacity Group	MALE Pred. $\dot{V}O_{2\ max}$ (ml/kg/min)		FEMALE Pred. $\dot{V}O_{2\ max}$ (ml/kg/min)	
14 - 19	High	51.76	(6.64)	45.03	(4.16)
	Low	34.62	(3.70)	23.22	(4.43)
	Mean	43.18		34.12	
20 - 29	High	45.32	(5.79)	38.38	(4.02)
	Low	28.48	(3.36)	23.12	(3.24)
	Mean	36.90		30.75	
30 - 39	High	39.41	(4.06)	34.96	(3.67)
	Low	25.10	(2.84)	20.63	(3.49)
	Mean	32.36		27.79	
40 - 49	High	33.44	(4.68)	30.78	(3.51)
	Low	20.74	(3.06)	17.86	(2.45)
	Mean	27.09		24.32	
50 - 59	High	30.90	(3.81)	28.00	(4.28)
	Low	20.52	(2.55)	16.19	(2.00)
	Mean	25.7		22.10	
60 - 74	High	28.90	(3.57)	23.20	(2.68)
	Low	18.00	(2.37)	13.58	(5.11)
	Mean	23.45		18.39	

and low groups and the null hypothesis of no difference between the age groups are both rejected. The alternate hypothesis of significant difference in aerobic capacity groups and of significant difference between age categories was accepted as tenable. Table H 1 (Appendix H) contains a summary of the results of the two way analysis of variance for the male subjects.

Scheffé contrasts were set up and F ratios calculated for all age groups. All age category high and low capacity groups were significantly different ($p < 0.01$). Table H II (Appendix H) contains the Scheffé contrasts for male subjects.

The analysis of female data also revealed significant F values at $p < 0.01$ for both A and B main effects and AB (age x capacity) interaction. The null hypothesis of no difference between the aerobic capacity of high and low groups and the null hypothesis of no difference between the age groups are, thus, both rejected. The alternate hypothesis of significant difference in aerobic capacity between high and low groups and between age groups was also accepted as tenable. Table H III (Appendix H) contains a summary of the results of the two way analysis of variance for the female subjects.

Scheffé contrasts were also set up and F ratios calculated for all female age groups. All age category high and low capacity groups, were significantly different ($p< 0.01$). Table H IV (Appendix H) contains the Scheffé contrasts for female subjects.

MEAN VALUES FOR VARIABLES

Mean values for males on physical activity level, (rated as 10, 20 or 30), smoking habits (rated as 10 or 20) and triceps fat (mm. of skinfold) are contained in Table V for males and for the females in Table VI. As indicated earlier, lower scores for physical activity indicate higher activity level. A rating of 10 for this variable indicates high physical activity level. The smoking habit score of 10 refers to non-smokers and 20 to smokers.

For male subjects the activity level of the high aerobic capacity group is greater than the low capacity group in all six age categories. Figure 2 illustrates this point graphically. Younger subjects tended to be the most active (14 to 19 years) and the 60 to 74 year old low capacity males the most inactive.

The smoking habits of the male subjects, as rated scores, are graphically illustrated in Figure 3 and in the form of percentage of smokers in each group in Figure 4. In age groups 14 to 19, 20 to 29, 40 to 49 and 60 to 74 years the low aerobic capacity group has the greater number of smokers, with the high aerobic capacity group having a similar number of smokers in the 30 to 39 year age group and more smokers in the 50 to 59 year bracket.

TABLE V

Mean Values and Standard Deviations for Male Subjects For Physical Activity Level, Smoking Habits and Triceps Fat

Age Group	Capacity Group	Activity (rating)	Smoking (rating)	% Smokers	Fatness (mm)
14-19	High	15.42 (6.44)	11.25 (3.31)	12.5	6.98 (1.56)
	Low	22.69 (7.10)	12.69 (4.44)	29.9	9.42 (3.78)
	Mean	19.06	11.97	20.0	8.2
20-29	High	22.14 (7.73)	12.5 (4.33)	25.00	8.44 (2.92)
	Low	27.58 (5.52)	16.36 (4.81)	73.6	11.36 (4.34)
	Mean	24.86	14.43	45.9	9.9
30-39	High	21.63 (8.17)	14.29 (4.95)	42.9	9.26 (3.80)
	Low	27.14 (5.35)	14.29 (4.95)	42.9	13.47 (5.56)
	Mean	24.39	14.29	42.9	11.37
40-49	High	25.20 (7.55)	12.8 (4.49)	28.0	9.13 (3.55)
	Low	28.15 (3.88)	13.70 (4.83)	37.0	13.03 (4.81)
	Mean	26.68	13.25	32.7	11.08
50-59	High	25.00 (7.42)	14.00 (4.90)	40.0	9.37 (4.17)
	Low	25.79 (6.74)	11.58 (3.65	15.8	11.24 (3.86)
	Mean	25.40	12.79	28.2	10.31
60-74	High	26.00 (4.90)	13.00 (4.58)	30.0	8.37 (1.32)
	Low	29.09 (2.88)	14.55 (4.98)	45.5	9.87 (2.25)
	Mean	27.55	13.78	38.1	9.12

TABLE VI

Mean Values and Standard Deviations for Female Subjects For Physical Activity Level, Smoking Habits and Triceps Fat

Age Group	Capacity Group	Activity (rating)	Smoking (rating)	% Smokers	Fatness (mm)
14-19	High	20.91 (7.12)	12.42 (4.29)	24.2	14.13 (4.45)
	Low	27.32 (5.42)	13.42 (4.74)	34.1	18.55 (6.66)
	Mean	24.12	12.92	29.7	16.34
20-29	High	25.50 (6.69)	14.50 (4.98)	45.0	14.55 (4.35)
	Low	27.91 (4.07)	13.49 (4.77)	34.9	16.36 (5.54)
	Mean	26.71	14.00	39.8	15.46
30-39	High	24.13 (7.39)	13.26 (4.68)	32.6	15.17 (4.71)
	Low	27.76 (4.64)	12.65 (4.42)	25.5	19.04 (6.62)
	Mean	25.95	12.96	29.5	17.11
40-49	High	22.96 (6.56)	12.95 (4.38)	25.9	16.99 (5.14)
	Low	26.90 (5.93)	12.76 (4.47)	27.6	20.50 (5.85)
	Mean	24.93	12.86	26.8	18.75
50-59	High	27.41 (4.38)	12.96 (4.57)	29.6	16.93 (6.08)
	Low	26.15 (5.60)	12.69 (4.44)	26.9	21.33 (5.68)
	Mean	26.78	12.83	28.3	19.13
60-74	High	25.33 (6.18)	13.33 (4.71)	33.3	19.22 (5.67)
	Low	25.79 (6.74)	12.11 (4.08)	21.1	18.74 (5.18)
	Mean	25.56	12.72	26.5	18.98

Figure 5 illustrates the mean values for triceps fat in the six male age categories. In all cases the low aerobic capacity group have the greater mean value for the triceps skinfold measure. The greatest difference occurs in the third and fourth age categories.

With the exception of age group 5 (50 to 59 years), the female high aerobic capacity group were more active than their low capacity counterparts. Figure 6 illustrates the activity levels for both groups over the entire age range. The most active group were the 14 to 19 year old high aerobic capacity group as was the case with the males. The most inactive groups were the younger low aerobic capacity females, particularily the second group (20 to 29 years) and third age group (30 to 39 years).

The smoking habits of the female subjects are illustrated in Figures 7 and 8. All age groups except the 14 to 19 year old high aerobic capacity group had a higher proportion of smokers than the low capacity group. The 14 to 19 year old group exhibited a greater percentage of smokers in the low capacity group.

The triceps fat measurement was greater in the low aerobic capacity group at all ages up to but not including the 60 to 74 year group. In this group the high capacity group had a slightly higher mean triceps skinfold measure. Figure 9 illustrates graphically the differences in the fat measurement between the two groups for the six age categories under consideration.

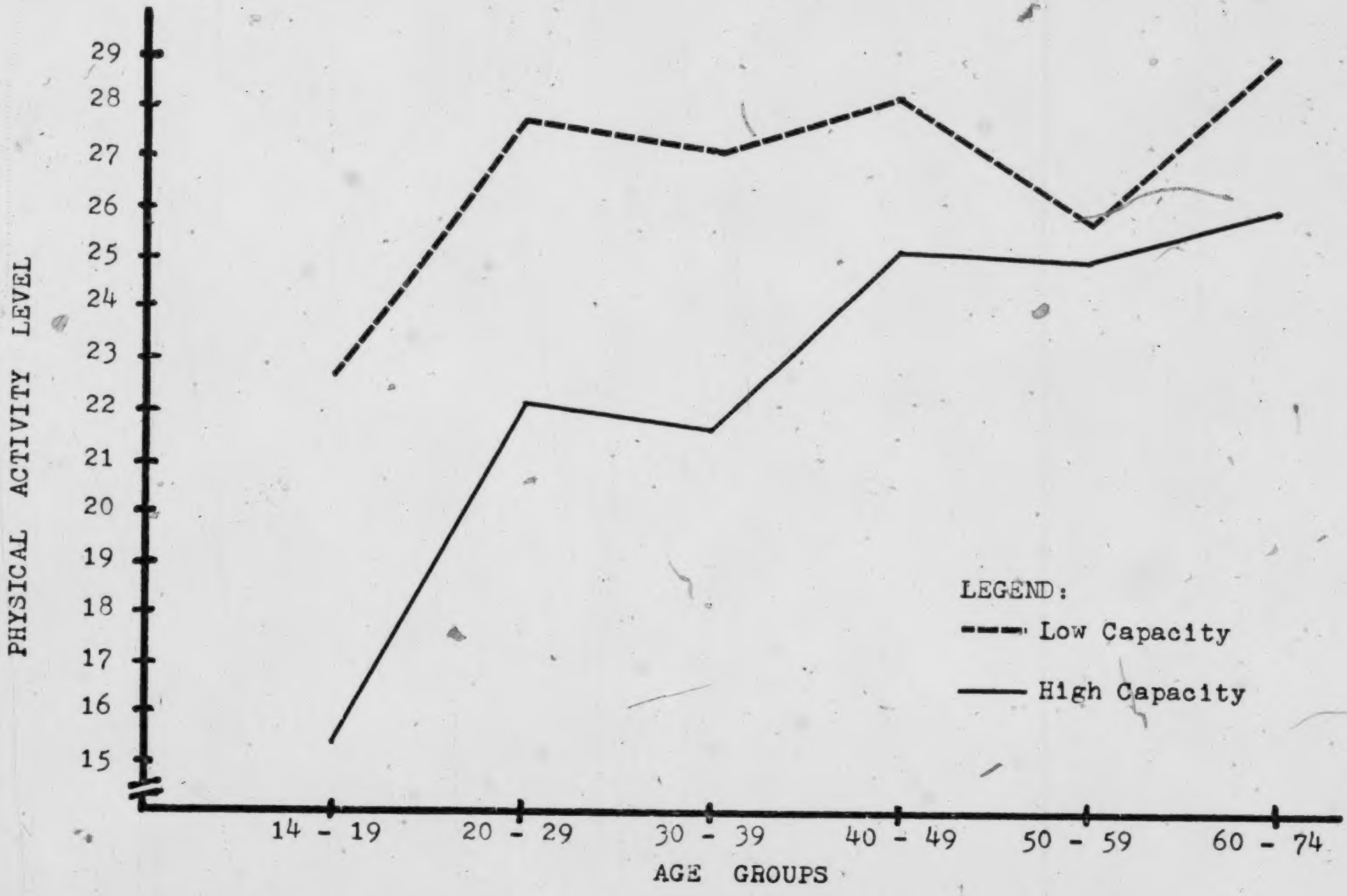


FIGURE 2: Mean Physical Activity Level Values for Male Subjects

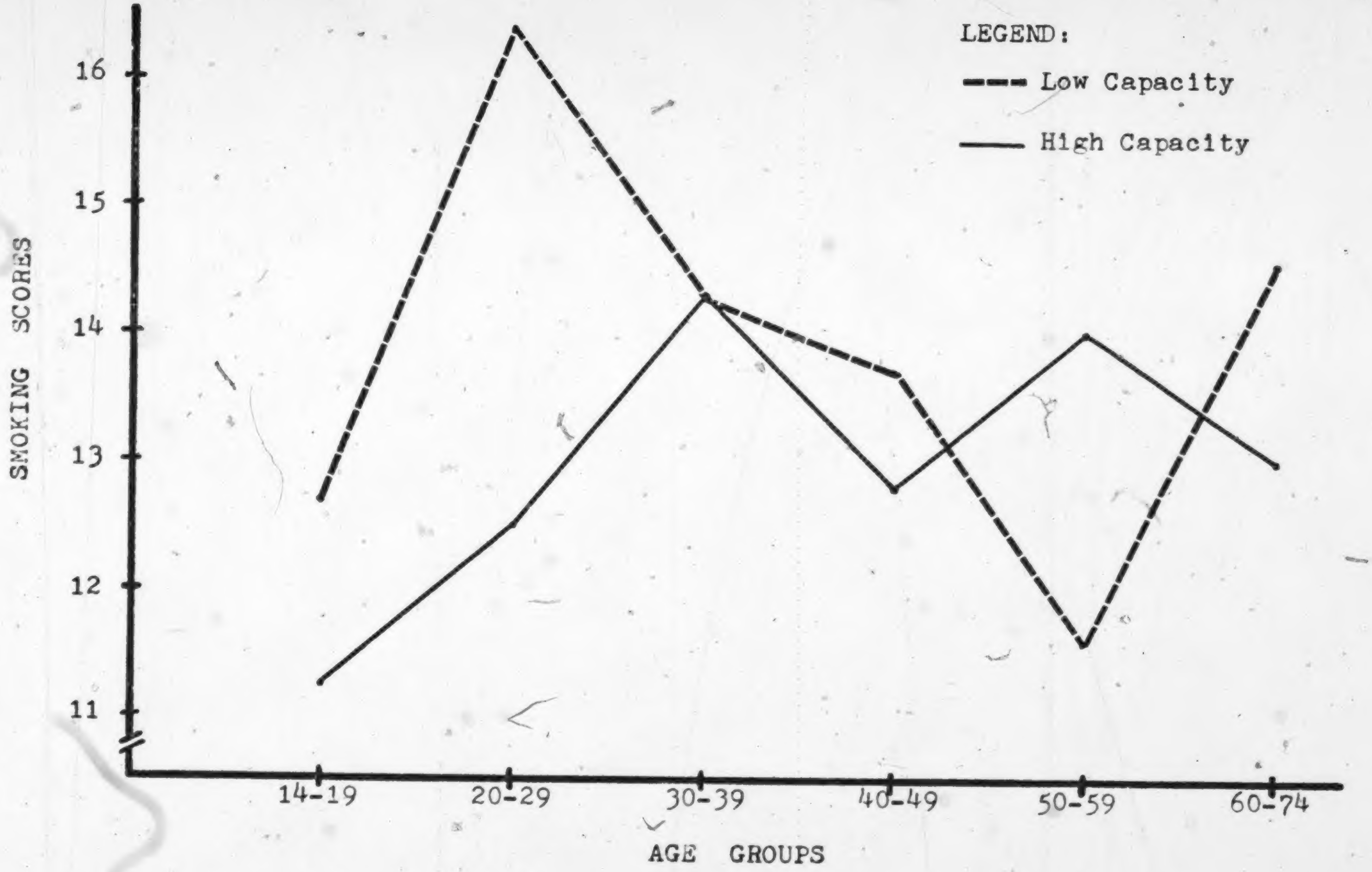


FIGURE 3: Mean Smoking Scores For Male Subjects

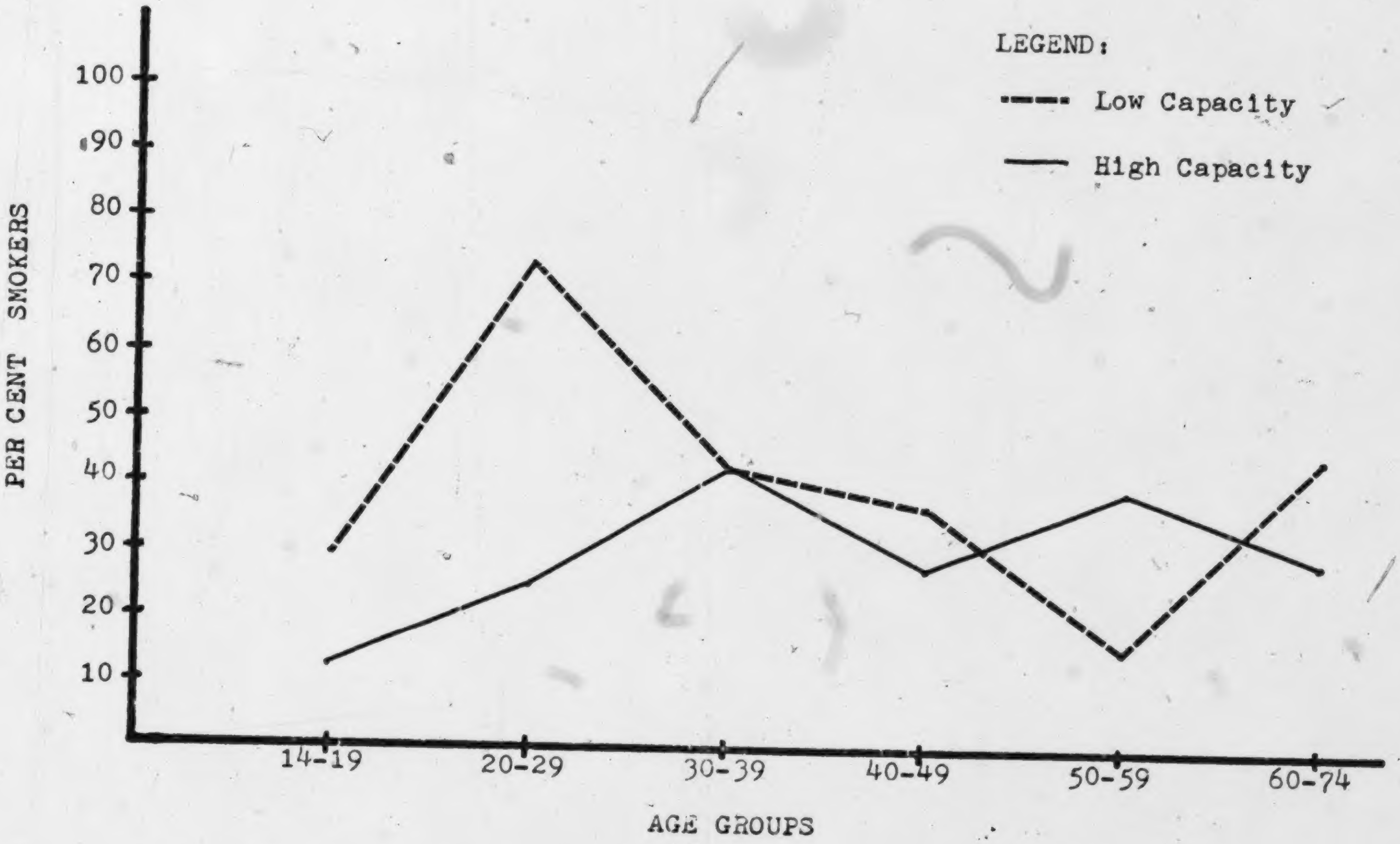


FIGURE 4: Number of Male Smokers Expressed as a Percentage

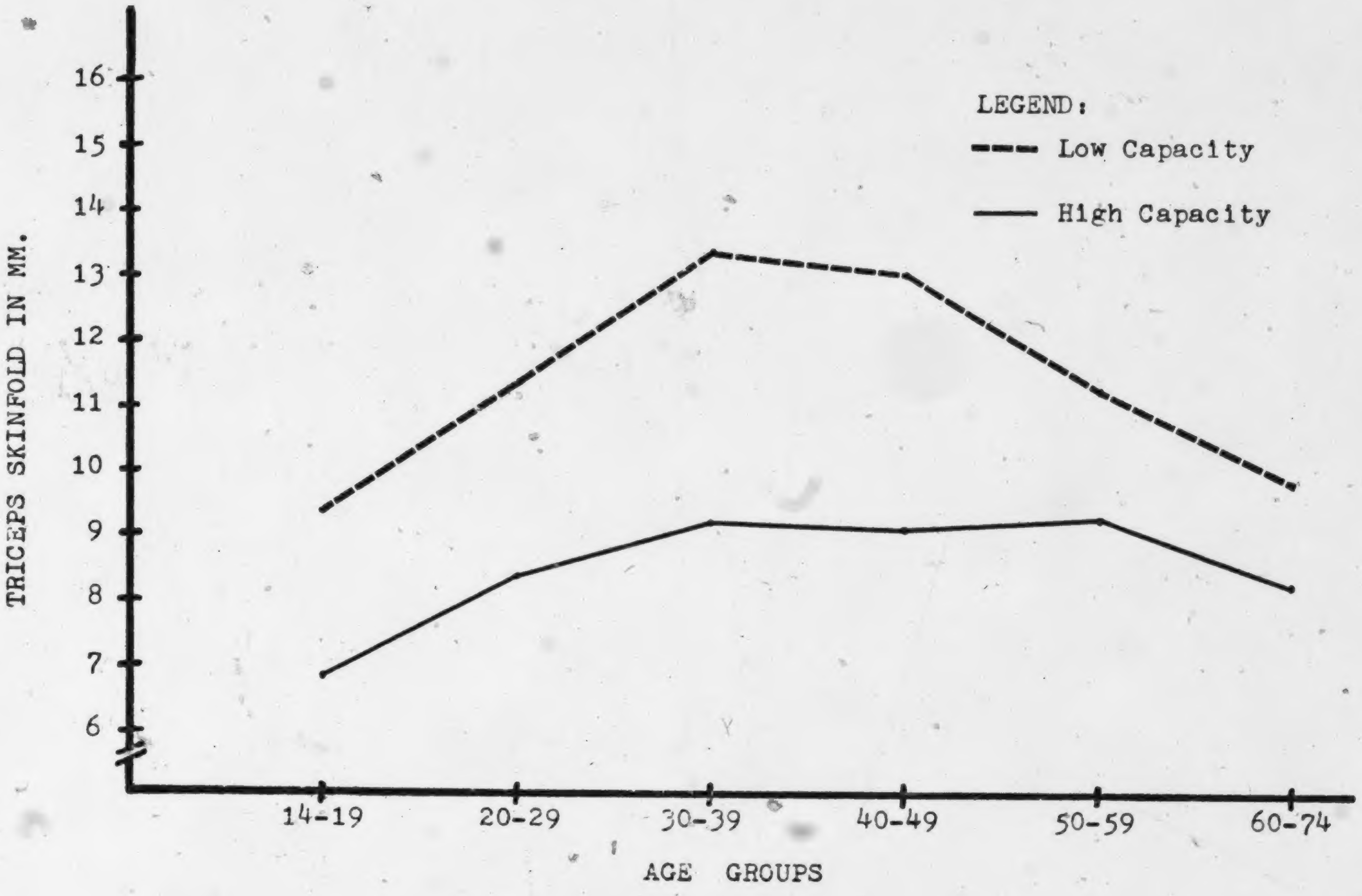


FIGURE 5: Mean Triceps Skinfold Measures for Male Subjects

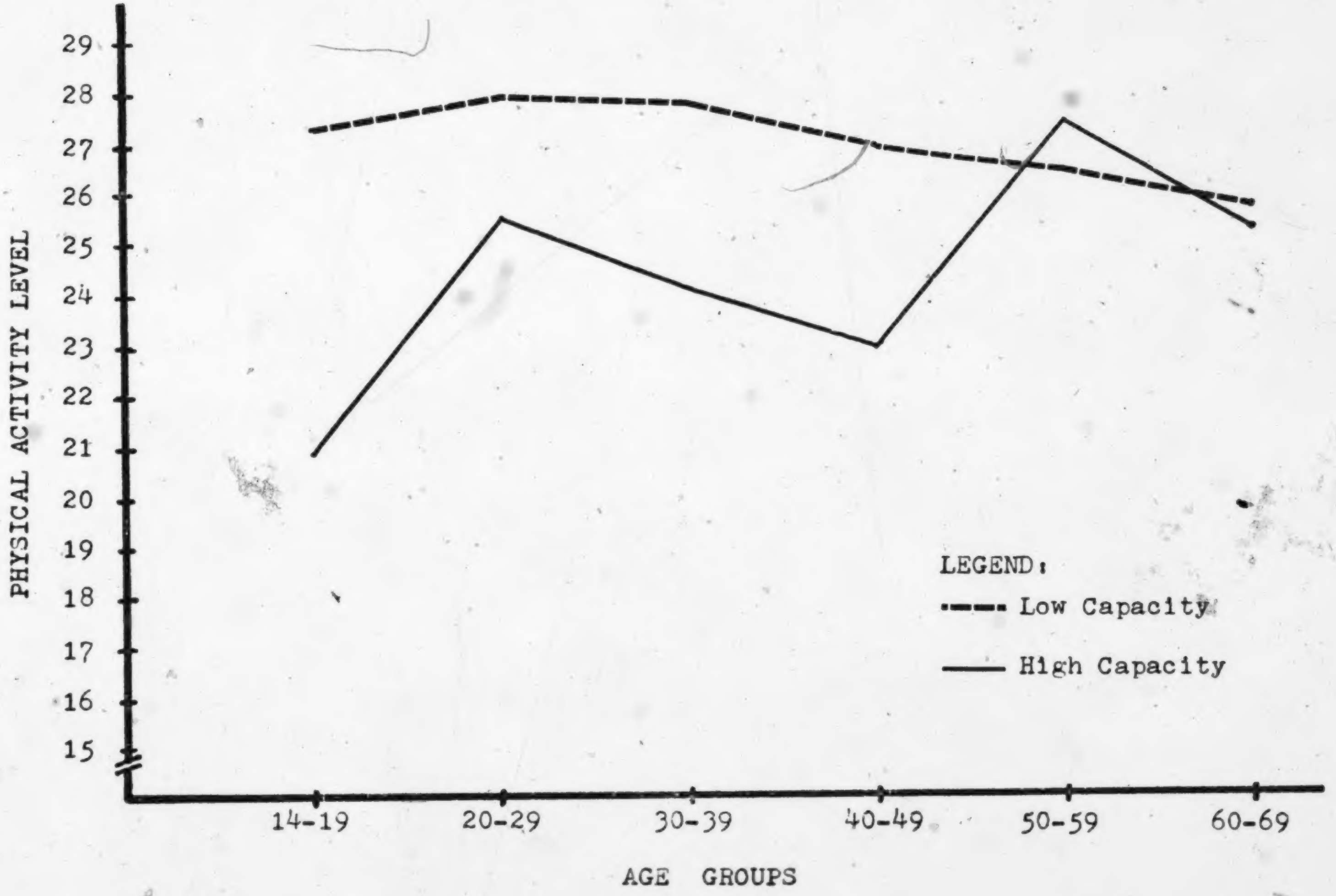


FIGURE 6: Mean Physical Activity Level Values For Female Subjects

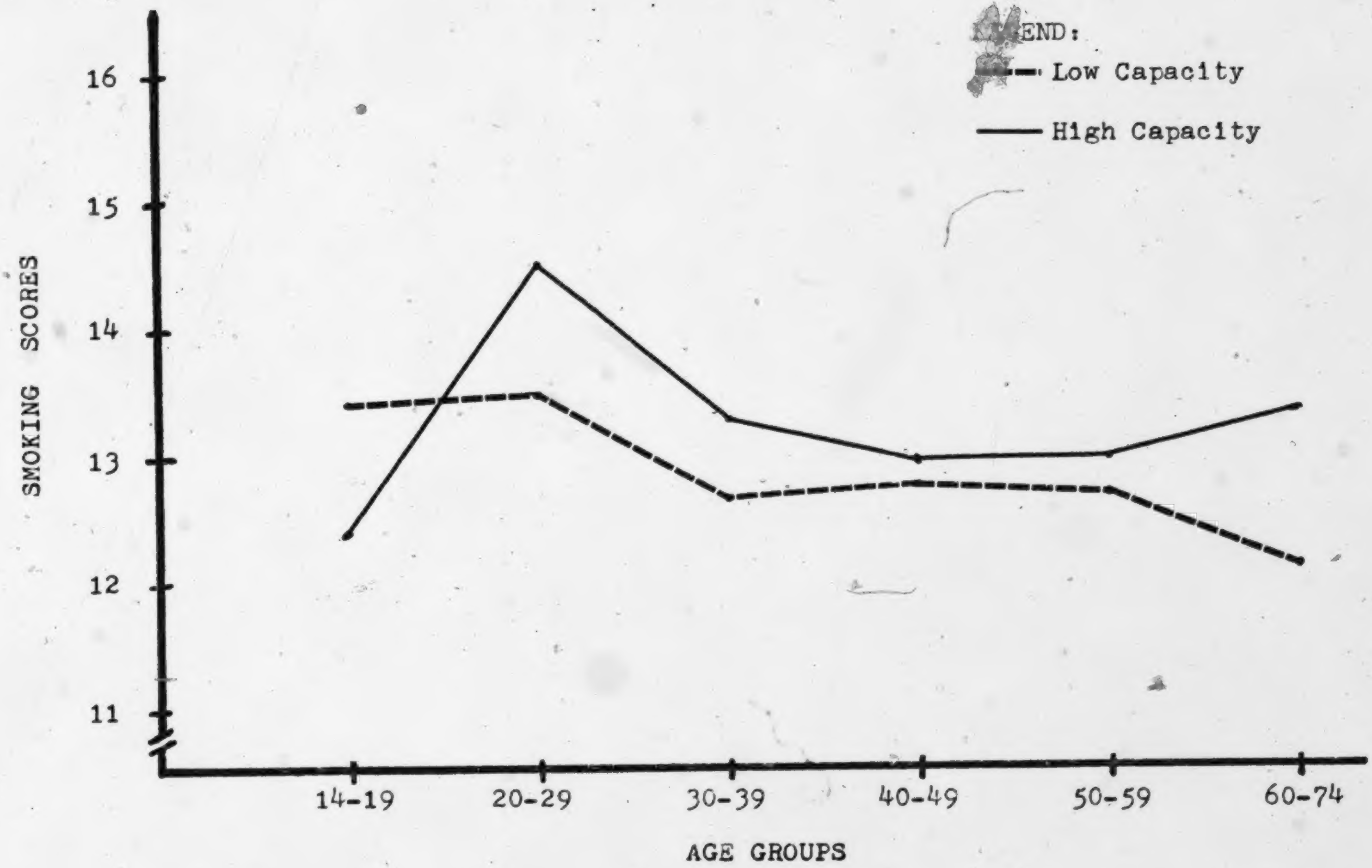


FIGURE 7: Mean Smoking Scores For Female Subjects

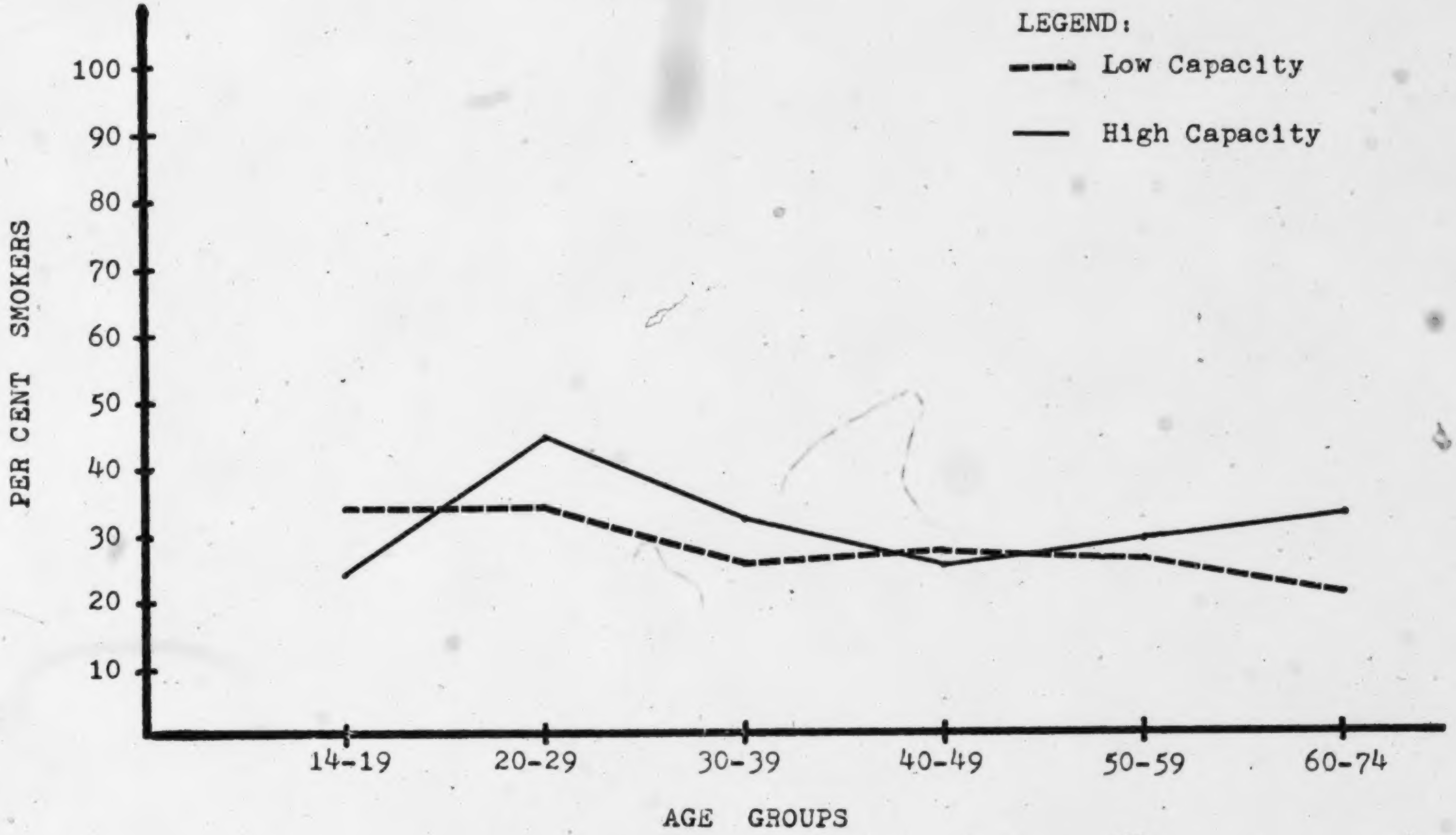


FIGURE 8: Number of Female Smokers Expressed as a Percentage

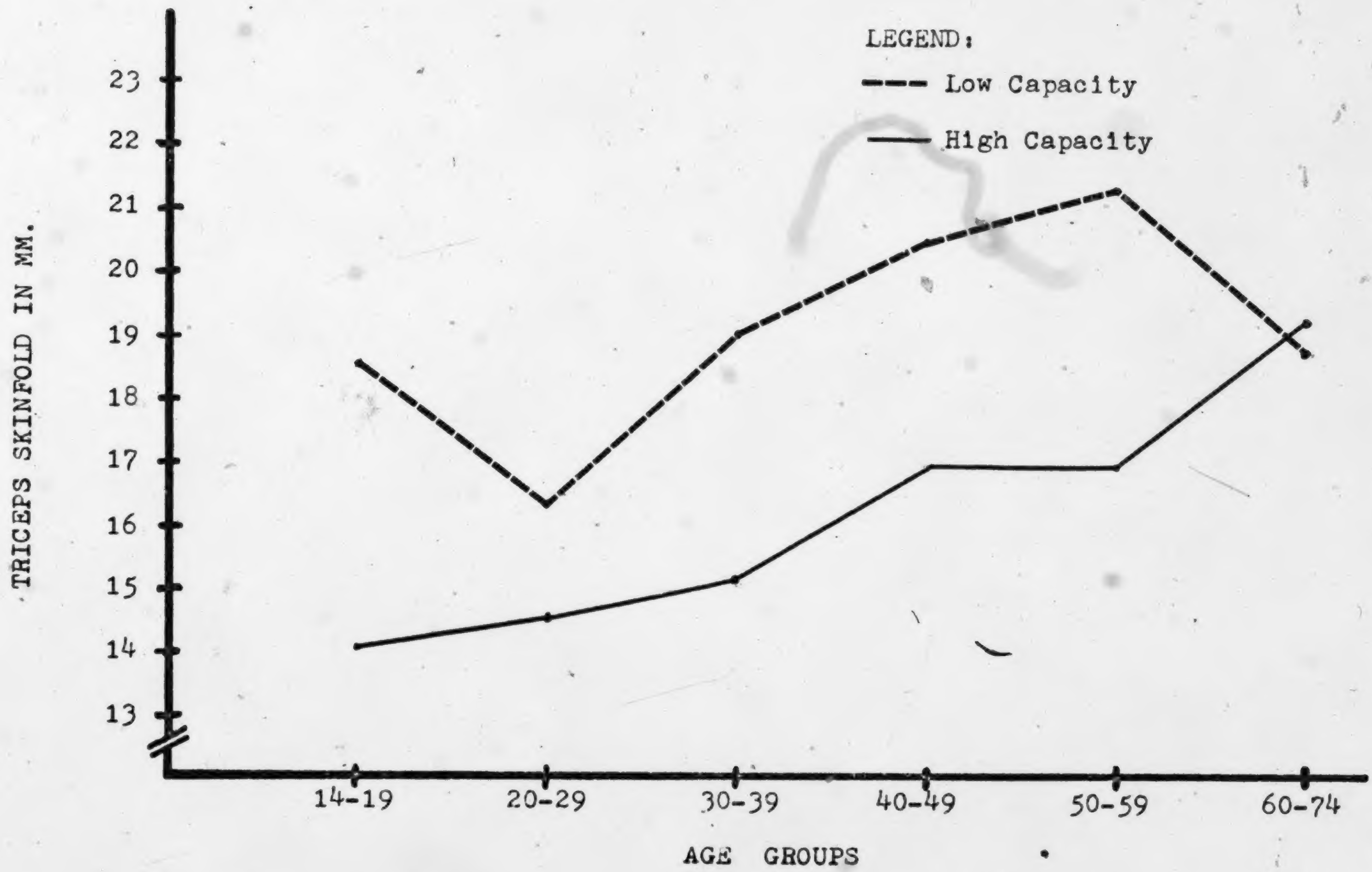


FIGURE 9: Mean Triceps Skinfold Measures For Female Subjects

MULTIVARIATE ANALYSIS WITHIN AGE GROUPS

Hotellings' T^2 Test

Table H V (Appendix H) summarizes the results of the Hotellings' T^2 tests performed on the male data.

Significant differences were found between the high and low aerobic capacity groups for the 14 to 19 year olds ($p < 0.01$), 20 to 29 year olds ($p < 0.01$), 30 to 39 year olds ($p < 0.01$), and the 40 to 49 year olds ($p < 0.05$). Neither the 50 to 59 year old group nor the 60 to 74 year old group showed significant differences between the two capacity groups on the three variables. As well, neither of these two age categories revealed significant differences on the three variables considered independantly.

In the 14 to 19 year group, multiple comparisons revealed that the high and low aerobic capacity groups were significantly different in physical activity level ($p < 0.01$) but not in terms of smoking habits or fatness.

The multiple comparisons of individual variables for the 20 to 29 year group showed significant differences in all three variables: activity ($p < 0.05$), smoking ($p < 0.05$), and fatness ($p < 0.05$).

The 30 to 39 year old high and low capacity groups were significantly different in activity level ($p < 0.01$) and fatness ($p < 0.01$) but not smoking.

Multiple comparisons of individual variables in the 40 to 49 year old group revealed a significant difference in fatness ($p < 0.05$) but not in activity level or smoking habits.

Table H VI (Appendix H) contains the results of the Hotellings' T^2 tests and multiple comparisons for each of the six age groups of female subjects.

In the 14 to 19 year age group the high and low capacity groups were significantly different ($p < 0.01$) in terms of the three variables that were considered. The multiple comparisons revealed that the two groups were significantly different in activity level ($p < 0.01$) and fatness ($p < 0.05$) but not significantly different in smoking habits.

The 20 to 29 year old group did not show a significant difference between the high and low capacity groups on the three variables.

The 30 to 39 year old high and low capacity groups were significantly different on the three variables ($p < 0.01$). Considering the variables individually resulted in only a significant difference in the fatness of the two aerobic capacity groups ($p < 0.05$) with no significant difference in either activity level or smoking.

The 40 to 49 year old high and low capacity groups were also significantly different ($p < 0.05$) in terms of the three discriminant variables with no significant differences individually among them.

The 50 to 59 and 60 to 74 year old high and low aerobic capacity groups were not significantly different in terms of the three variables considered.

Discriminant Function Analysis

Table H VII (Appendix H) provides a summary of the discriminant function weights and the F ratio calculated from the means of the linear combination for the male subjects.

The linear combination for the 14 to 19 year old males produced significantly different ($p < 0.01$) group means for the high and low aerobic capacity groups on the three variables. The order of influence in producing the optimum linear combination for this group was 1) fatness, 2) activity and 3) smoking habits with smoking habits playing an almost insignificant role.

The group means for the 20 to 29 year old group calculated from the linear combination were also significantly different ($p < 0.01$). The order of weights in descending order was different from the younger males, with smoking habits and activity being reversed: (1) fatness, 2) smoking habits, and 3) activity.)

The 30 to 39 and 40 to 49 age categories also produced significantly different group means ($p < 0.01$ and $p < 0.05$ respectively) based on the linear combinations. Both groups also exhibited the same weight order : 1) fatness, 2) activity level and 3) smoking habits. The weights for activity level and smoking habits in the 40 to 49 age category, however, were quite similar.

The group means calculated from the linear combinations for the 50 to 59 and 60 to 74 age categories were not significantly different ($p > 0.05$) so that further consideration of the discriminant weights is unwarranted.

Table H VIII (Appendix H) contains the summary of the discriminant function analysis of the female high and low aerobic capacity groups on the three variables.

The linear combination for the 14 to 19 age category produced significantly different group means ($p < 0.01$) calculated by use of the linear combination. The descending order of discriminant weights for this group was: 1) activity level, 2) fatness and 3) smoking habits.

The group means calculated for the 20 to 29 year old group by the linear combination were not significantly different ($p > 0.5$). The weights, however, were similar to those in the younger age category.

The 30 to 39 and 40 to 49 age categories both produced significantly different group means ($p < 0.01$ and $p < 0.05$ respectively) calculated by the discriminant function weights. The order of the discriminant function weights were also the same for these two age groups: 1) fatness, 2) activity level and 3) smoking habits.

Neither of the two older age categories, 50 to 59 and 60 to 74 produced significantly different group means ($p > 0.05$) calculated by use of the discriminant weights.

MULTIVARIATE ANALYSIS BETWEEN AGE GROUPS

Two Way MANOVA

Table H IX (Appendix H) contains a summary of the two way MANOVA performed on the male data. Both A and B main effects were significant ($p < 0.01$). The AB interaction (age x capacity) was not significant. Thus, the null hypothesis of no difference between high and low capacity groups on the three variables considering all subjects is rejected. Multiple comparisons A1-A2 for the individual variables revealed significant differences between the capacity groups on activity level and fatness ($p < 0.01$) but not on smoking habits ($p > 0.05$).

The null hypothesis of no difference between age groups on the three variables is also rejected (B main effects). Individual comparisons of variables between age groups revealed only one significant result, however. The activity level between age group 14 to 19 years and the age group 40 to 49 years is significantly different ($p < 0.01$). All other contrasts are not significantly different. Thus, it must be concluded that it is a particular combination of the variables that produces the overall significant difference and perhaps some age groups provide more influence in this regard than others.

Table H X (Appendix H) provides a summary of the two way MANOVA performed on the female data. The results are quite similar to the male results in that the A and B main effects are both significant ($p < 0.01$) and the

AB interaction effect is not ($p > 0.05$). Thus the null hypothesis of no difference between capacity groups (A effects) and the age groups (B effects) on the three variables is rejected.

Comparisons of the variables for individual capacity effect (A) revealed significant differences for activity level and fatness ($p < 0.01$) but not for smoking habits ($p > 0.05$). Individual comparisons of the variables between all age groups revealed no significant differences between any of the variables for any two age groups. Thus, as with the male data, it must be concluded that combined effects of the variables acted to produce the overall significant differences between age categories.

Discriminant Function Analysis

A summary of the discriminant function weights previously considered for male subjects is contained in Table H VII (Appendix H). Consideration of only the first four age groups will be given since only these groups produced significant differences when the three variables are considered. In each of the four groups, the variable which exerts the greatest influence in separating the capacity groups is fatness. With one exception (20 to 29 year group), the second most influential variable is physical activity level with smoking being the least important. The 20 to 29 year group had smoking second and activity third. It may be recalled that in this age group there was an extremely large difference in per cent smokers between the low and high capacity groups: 73.6% and 25% respectively.

Table H VIII (Appendix H) contains the summary of discriminant function weights for female data. As with the male data, only those age categories (14 to 19 years, 30 to 39 years and 40 to 49 years) in which significant differences between the groups on the three variables were evident, were considered. In all three cases, the clearly most important variables were fatness and physical activity level. In the younger group (14 to 19 years) physical activity was the first weight with fatness being second. This order was reversed for the two older age groups 30 to 39 years and 40 to 49 years) but in all cases the weights appear to be similar. The weights for smoking habits were the lowest in all three cases.

SUBSTANTIATION OF MALE-FEMALE AEROBIC CAPACITY GROUP DIFFERENCES

A two way ANOVA was performed on the male-female high aerobic capacity and low aerobic capacity groups to test the null hypothesis of no difference between the male and female groups in predicted $\dot{V}O_2$ max.

The analysis of the high capacity group revealed significant F values for both A and B main effects ($p < 0.01$) and AB (age x sex) interaction ($p < 0.05$). A summary of the results of the two way ANOVA on this data is contained in Table H XI (Appendix H). Thus, the null hypothesis of no difference between the high aerobic capacity male and female groups is rejected. Scheffé contrasts were set up and F ratios calculated for each age category. Appendix H Table H XII contains the results of the Scheffé contrasts for the high capacity male and female data. Significant F ratios were found for all age groups ($p < 0.05$).

The summary of results of the two way ANOVA on the low capacity male and female groups is contained in Table H XIII (Appendix H). The null hypothesis of no difference between low aerobic capacity male and female subjects is rejected on the basis of significant F values ($p < 0.01$) for A main effects. B main effects (age) were also significantly different ($p < 0.01$) as was the AB (age x sex) interaction ($p < 0.01$). As with the high aerobic capacity groups, Scheffé contrasts were set up and F ratios calculated for each age category. All age category male-female contrasts were significant ($p < 0.01$). Table H XIV (Appendix H) contains the results of the Scheffé contrasts for the low aerobic capacity data.

MULTIVARIATE ANALYSIS WITHIN HIGH AND LOW MALE-FEMALE CAPACITY GROUPS

Hotellings' T^2 Test

The Hotellings' T^2 test produced significant F ratios in every case ($p < 0.01$). Table H XV (Appendix H) summarizes these results and include the multiple comparisons determined for this data. In every one of the twelve analysis the null hypothesis of no difference between the male and female groups in terms of the variables physical activity level, smoking habits and fatness was rejected.

With one exception the only significantly different variable in each of the twelve cases was fatness ($p < 0.01$). The one exception was significant difference in physical activity level in the 14 to 19 year low aerobic capacity group. In all other cases the F ratio required for significance ($\alpha = 0.05$) was not exceeded. It, therefore, must be concluded that in all but one exceptional case the greatest individual contributor, of the variables considered, to producing the significant over all difference between the groups was fatness.

Discriminant Function Analysis

The conclusion previously reached regarding the contribution of individual variables to the difference between male and female subjects is corroborated by the results of the discriminant function analysis. Table H XVI (Appendix H) contains a summary of the discriminant function analysis results. In each of the twelve cases, the weight for fatness is the largest and hence must be considered the greatest contributor to the difference between the two groups.

In the 14 to 19 year age group, smoking habits was the second highest weight with activity level lowest for the high capacity group and reversed in the low capacity group, second activity level and third smoking

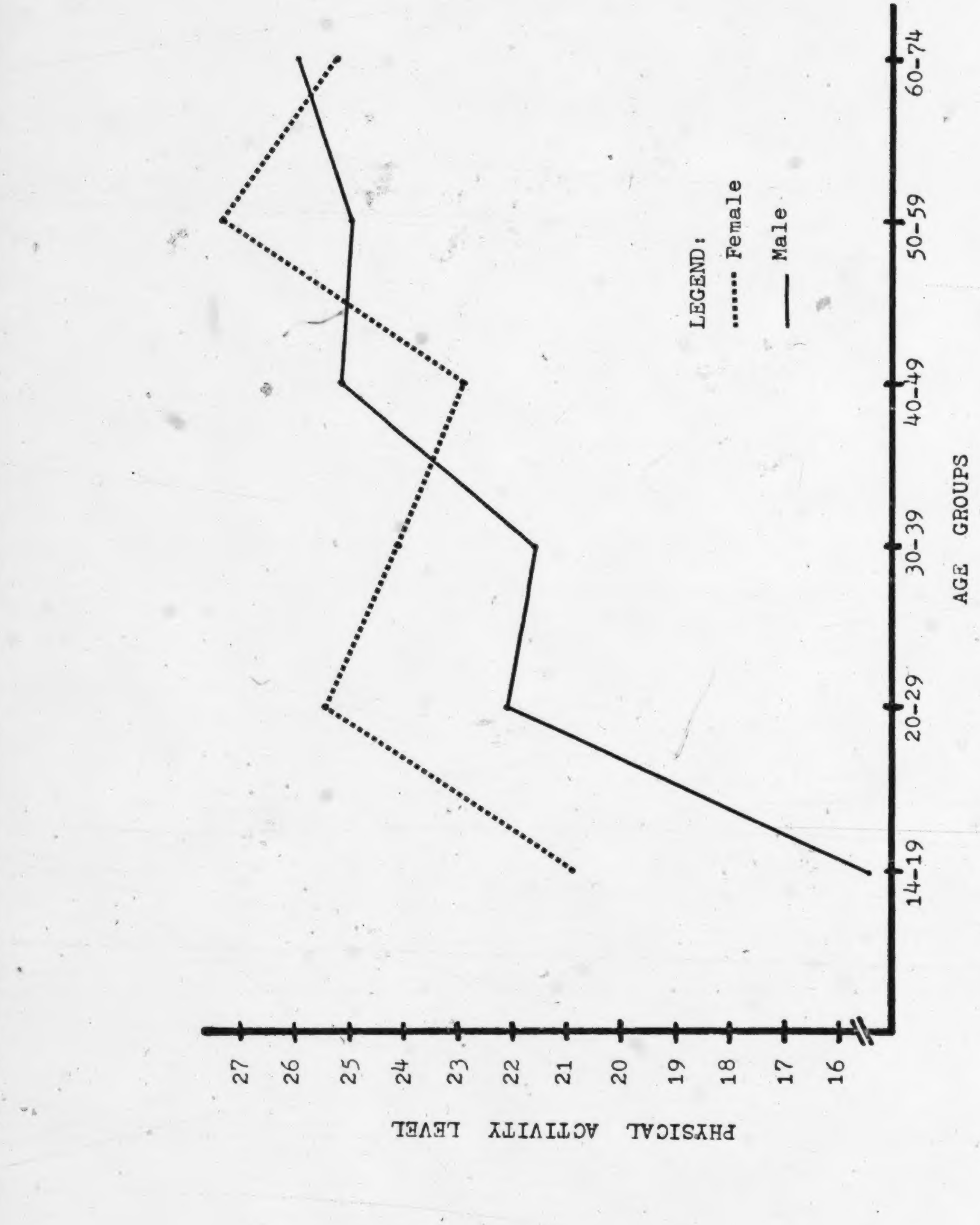


FIGURE 10: Mean Physical Activity Level Values For High Aerobic Male and Female Subjects

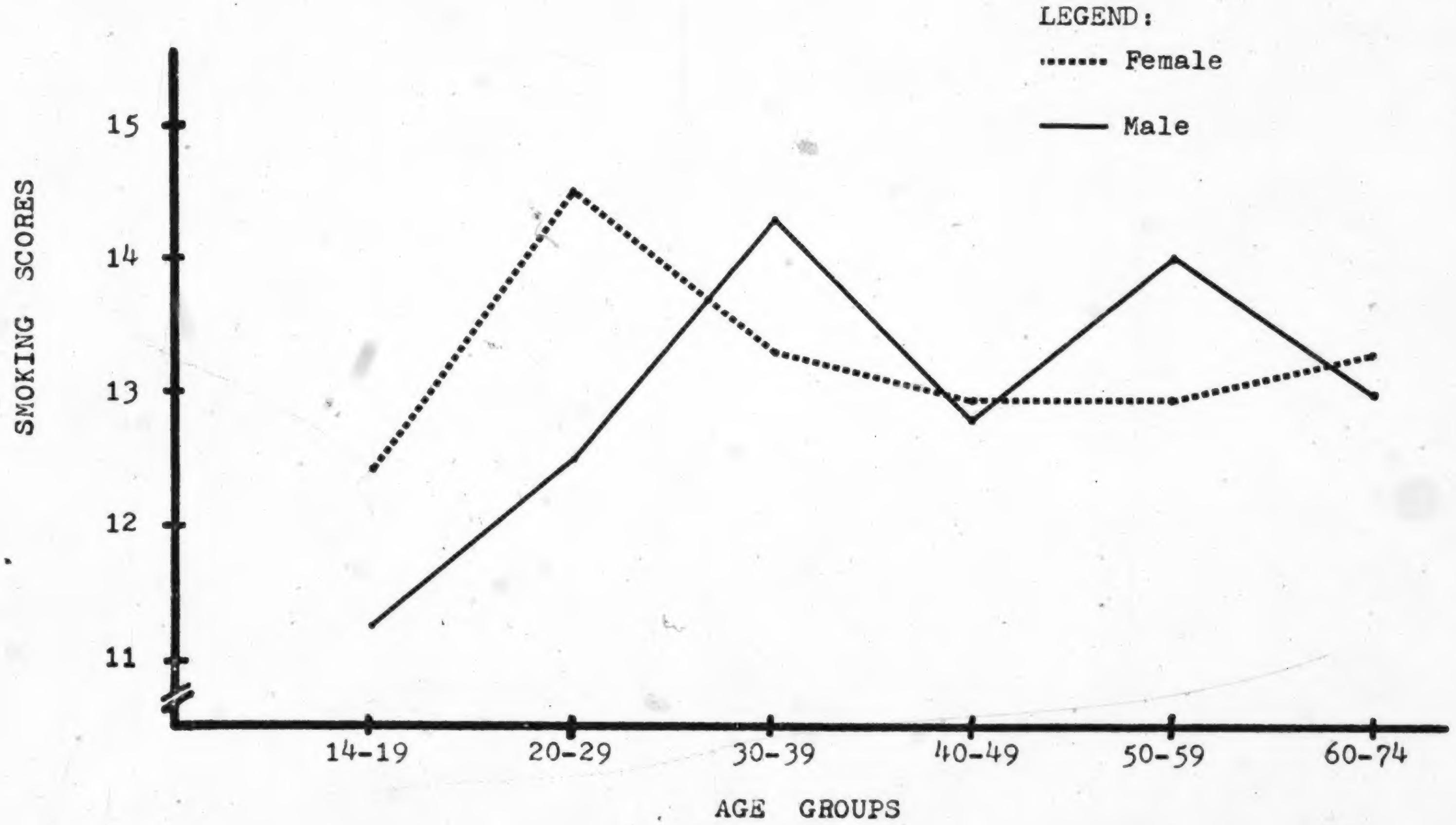


FIGURE 11: Mean Smoking Values for High Aerobic Capacity Male and Female Subjects

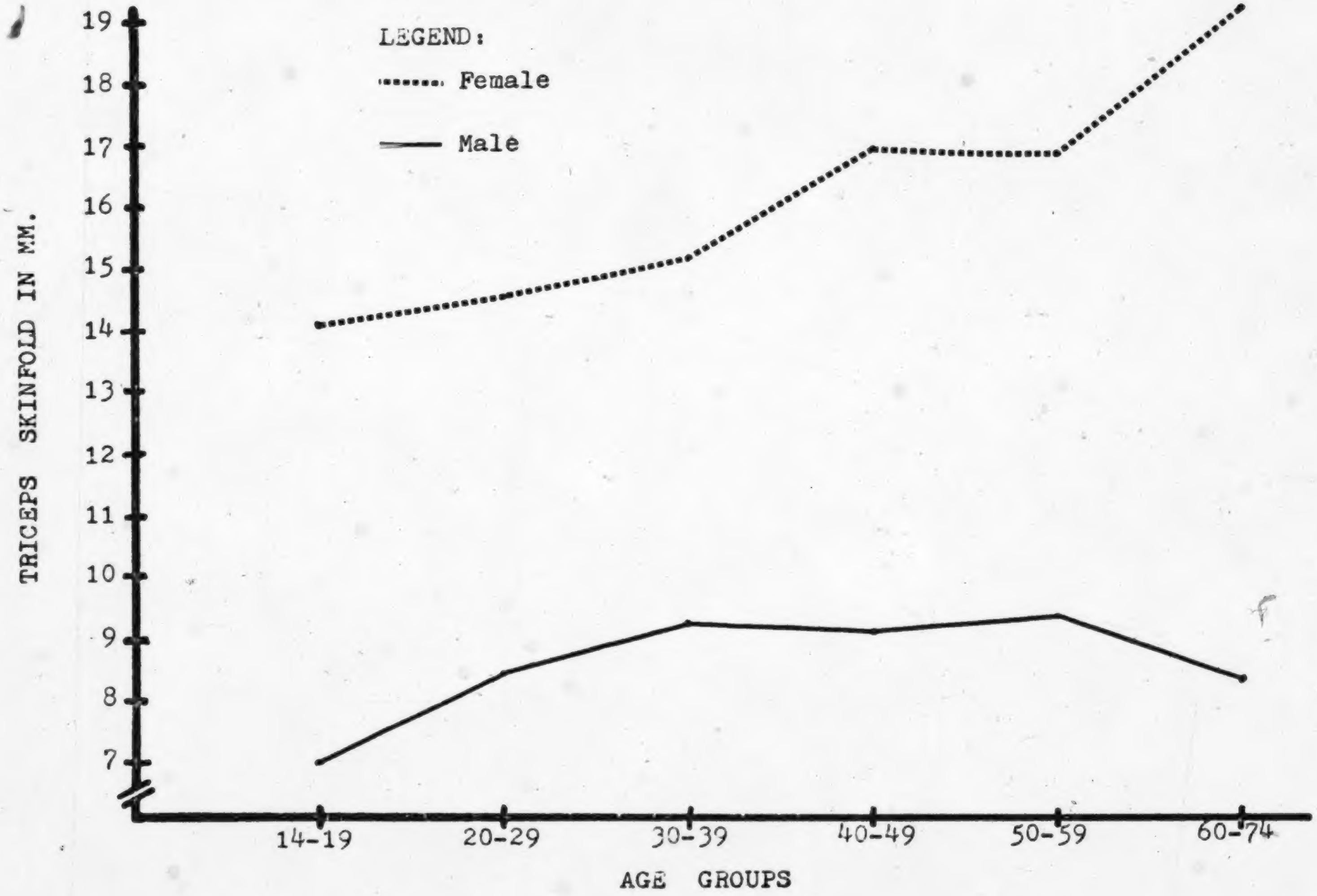


FIGURE 12: Mean Triceps Skinfold Values for High Aerobic Capacity Male and Female Subjects

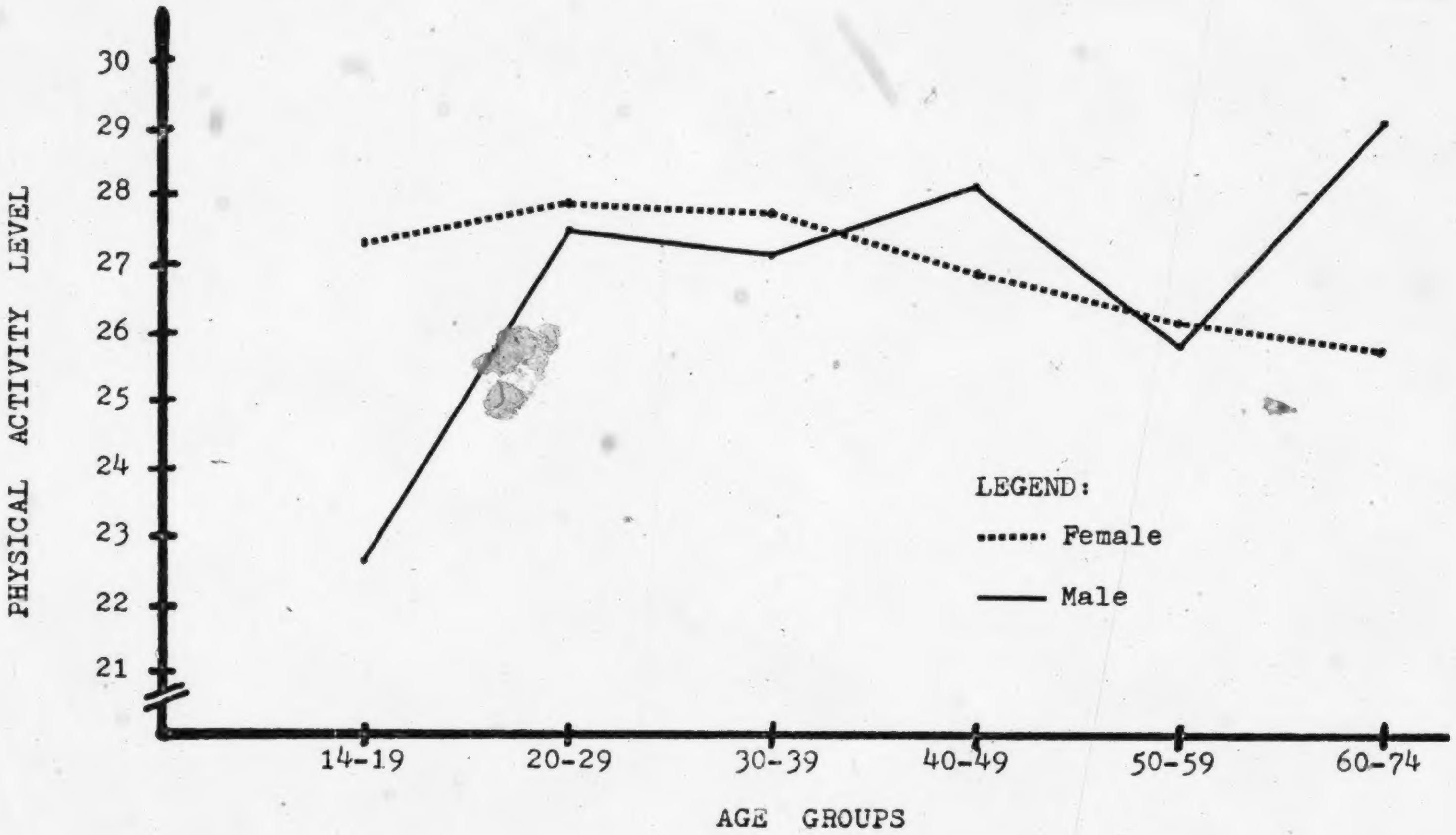


FIGURE 13: Mean Physical Activity Level Values for Low Aerobic Capacity Male and Female Subjects

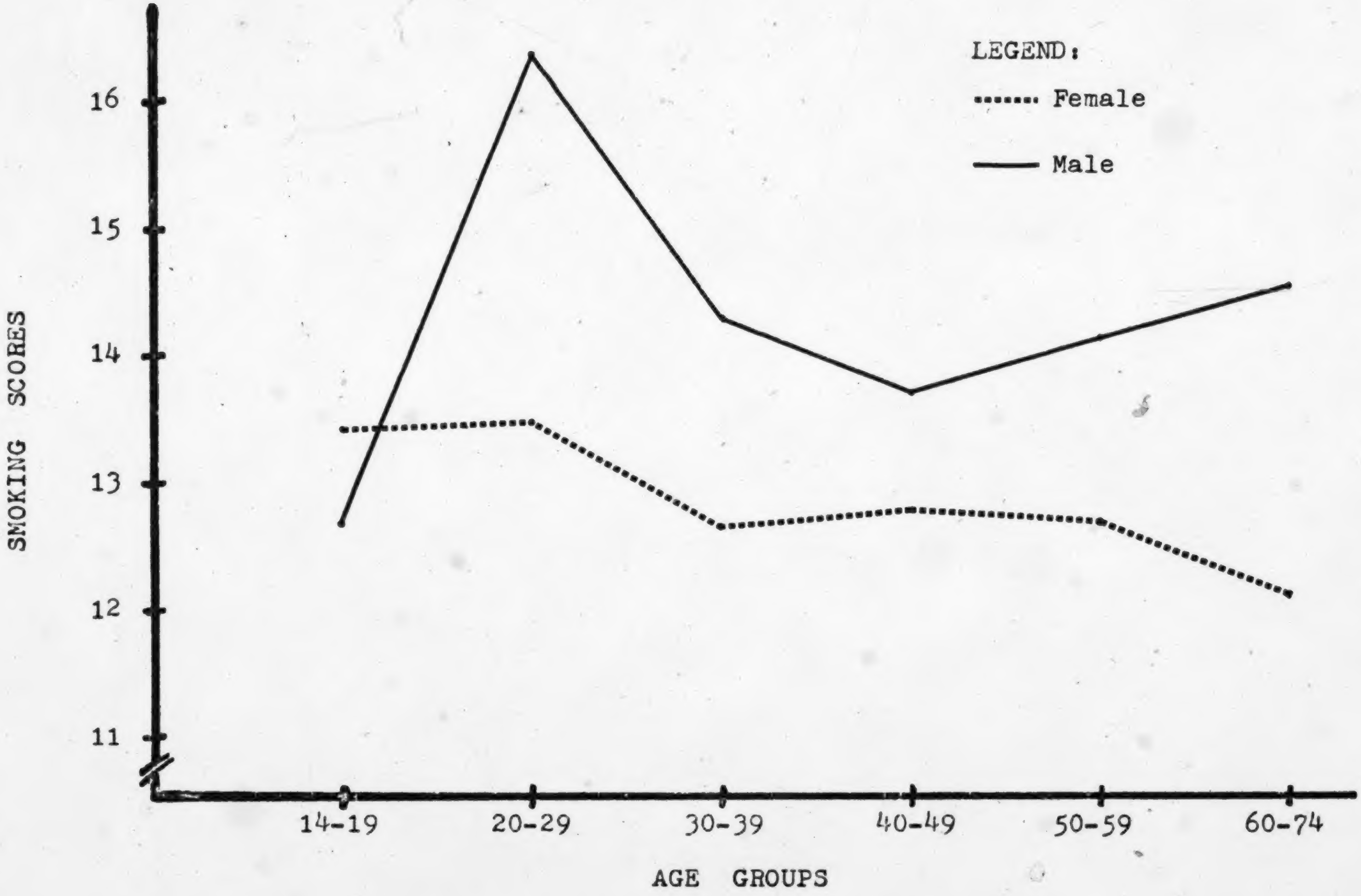


FIGURE 14: Mean Smoking Scores for Low Aerobic Capacity Male and Female Subjects

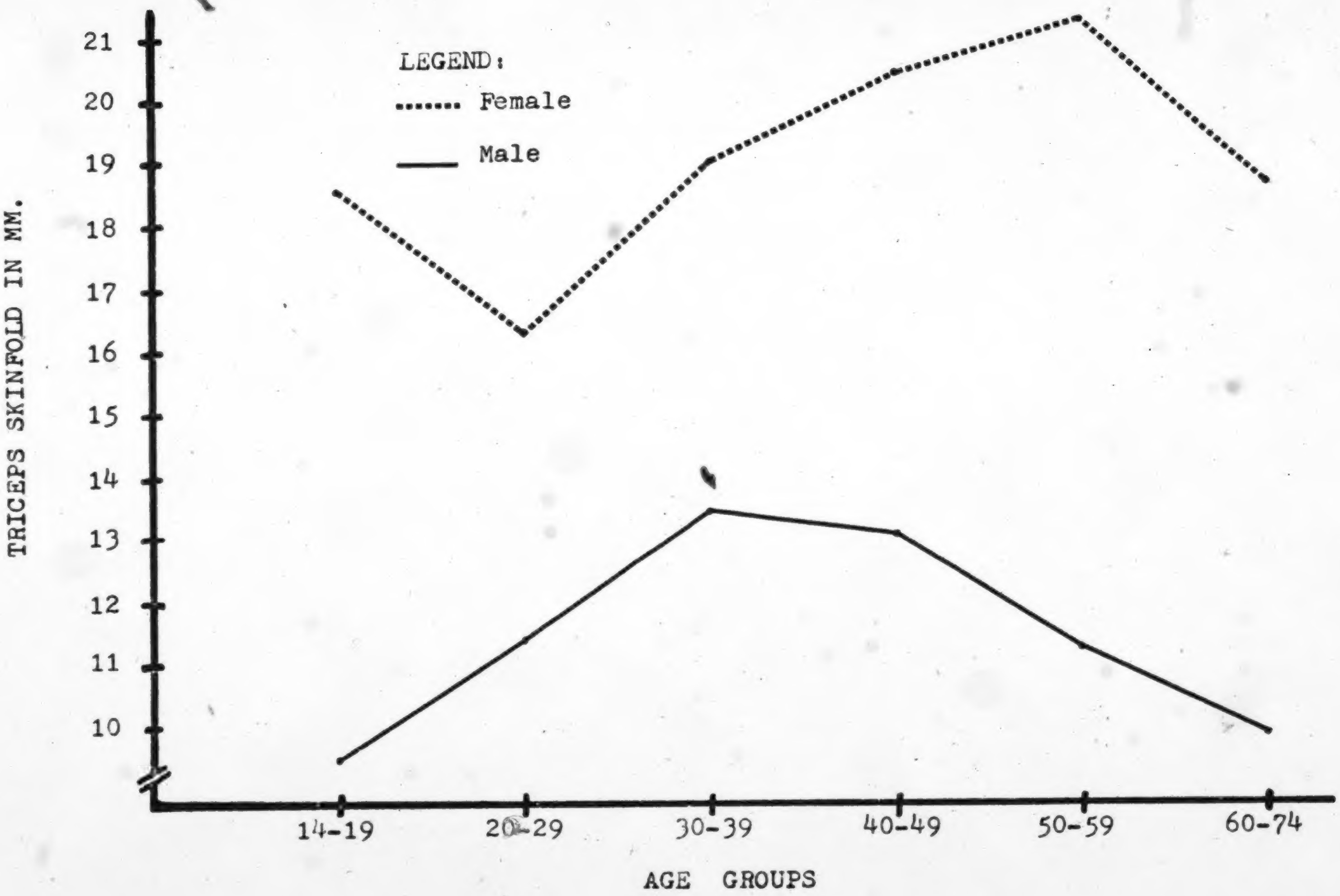


FIGURE 15: Mean Triceps Skinfold Values for Low Aerobic Capacity Male and Female Subjects

habits.

Smoking habits were the second highest weight and activity level was the third highest in the 20 to 29 year and the 30 to 39 year high and low aerobic capacity groups.

In the 40 to 49 year group the physical activity weights were second highest and smoking habits weighted third for both high and low aerobic capacity groups.

Activity level (second) and smoking habits (third) was the weight order for the 50 to 59 year high capacity group with the reverse the case for the low capacity groups.

The differences between the male-female high capacity group on the three variables are illustrated graphically in Figures 10, 11, and 12. Figures 13, 14 and 15 contain the same information for the low capacity male-female groups.

DISCUSSION

The $\dot{V}O_{2\ max}$ values obtained in this study are of particular interest when compared with other data in the literature. Bailey et al (16) have compared mean values for all age groups, both sexes with other mean data reported in the literature. The mean vaues were increased by 15% for this comparison as recommended by Shephard (157) since the $\dot{V}O_{2\ max}$ utilized is a predicted value from submaximal exercise on the bicycle ergometer. These authors concluded that the cardio-respiratory fitness level of this Canadian sample is lower than that of another sample tested in 1966 (157). The present group is also lower than data for Scandanavians reported by Shephard (157). These results were also compared to other Swedish data and the concensus was that on the whole this sample ranks far below the average Swedish norms. Comparison with American norms also revealed that this sample ranked below the average recommended for each age group. These comparisons led the authors to conclude that Canadian men and women as a group are physically unfit in terms of cardio-respiratory fitness levels.

Comparison of the high and low aerobic capacity group $\dot{V}O_{2\ max}$ values for this sample and data from the literature are presented for male subjects in Figure 16 and for female subjects in Figure 17.

The comparisons for the male data are predicted $\dot{V}O_{2\ max}$ values based on submaximal exercise on a bicycle ergometer with the exception of the data from I. Astrand (6) which is the average figure from a classification table for $\dot{V}O_{2\ max}$. The $\dot{V}O_{2\ max}$ for the high aerobic capacity group in each age category is very similar to the values reported by Shephard (164). The values reported by Bailey (17) are slightly below the high aerobic capacity group but well above the low aerobic capacity group. The values reported by Astrand are higher than the high aerobic capacity from this study in all age categories. Generally, the high capacity group is quite similar to the data reported by Shephard (164), Bailey (17) and Astrand (6).

Figure 17, which illustrates the female data, also utilizes the same classification table from Astrand's study (6) and a compilation of data on Canadian women by Shephard (157). The data for the high capacity group is very similar to the data reported by Shephard (157) and though lower at all age groups than Astrand's data (6) is quite similar as well.

The age and sex variations reported by I. Astrand (7) and others (8, 100, 110, 132, 141) are also observed in this data. That is, a consistent decrease in aerobic power from the young age group to the older age group and the mean values for males consistently higher than for females at all age categories. There is, however, a large overlap in mean values for male and female values when comparing high female capacity and low male capacity groups. The high female aerobic capacity groups were consistently higher in $\dot{V}O_{2\ max}$ than the low aerobic capacity male group. This relationship is illustrated in Figure 18.

The mean values for high and low aerobic capacity groups in physical activity levels are what might be expected from the literature related to training and physical activity and its affect on aerobic capacity (70, 108, 179). That is, the more physically active individuals are, the more likely they are to have a greater $\dot{V}O_{2\ max}$. For the male subjects, the self rated physical activity data show higher activity levels for the high capacity group in all six age categories. As well, the most active group is the youngest, with activity levels decreasing as age increases; the most inactive group is the oldest, as might be expected. Mean physical activity ratings for females also follow the same general trend as the males in that the high aerobic capacity group tends to be more active than their low aerobic capacity counterparts. The age variation in activity levels is not similar to the males since the two most active groups are the youngest and the oldest (14 to 19 years and 60 to 74 years).

Comparisons of smokers and non-smokers between the high and low aerobic capacity groups is not consistent across the age groups. For males the low aerobic capacity subjects had more smokers in four age categories, the same in one group and fewer smokers in one group. Overall, however, the mean percentages covering all age groups shows 29.7% smokers in the high capacity group and 40.8% smokers in the low capacity group. These results agree with the findings of Cooper (41), Peterson and Kelley (134) and Glassford and Howell (77). The smoking habits of the female subjects are quite different than the males when high and low aerobic capacity groups are considered. In all but the youngest age group the high aerobic capacity subjects had the greater percentage of smokers. Over all the age ranges the high capacity group had a mean percentage of 31.8% smokers and the low capacity group 28.4%. This data would tend to support the findings of Blackburn et al. (25), Shapiro and Patterson (154) and Chevalier et al. (38) who found little or no difference in $\dot{V}O_{2\ max}$ between smoking and non-smoking male subjects.

Comparisons of triceps fat measures from this study are compared to data from the Canadian Height-Weight Survey of 1956 (135) in Figure 19 for males and Figure 20 for females. Figure 19 also includes data for male subjects from Bailey (17). At all age levels for male subjects, the values recorded for Canadians in 1956 were lower than the present high capacity group values. The values reported by Bailey (17) fall between the high and low capacity groups for all age groups except age group six (60 to 74 years) in which the Bailey values are higher than those of the low capacity group. This trend is also observed in the female data with the Canadian data from 1956 being lower than the high aerobic capacity group at all ages except approximately 50 to 60 years. The low aerobic capacity group is higher in the triceps measure than the high capacity group except at the 60 to 74 year age range and higher at all age levels than the 1956 data. The calipers used in the 1956 study, though not Harpenden calipers, meet the specifications set for the Harpenden calipers (172).

These comparisons would tend to suggest that Canadians have become fatter in the past 17 years if the present data can be considered at all representative of Canadians in general.

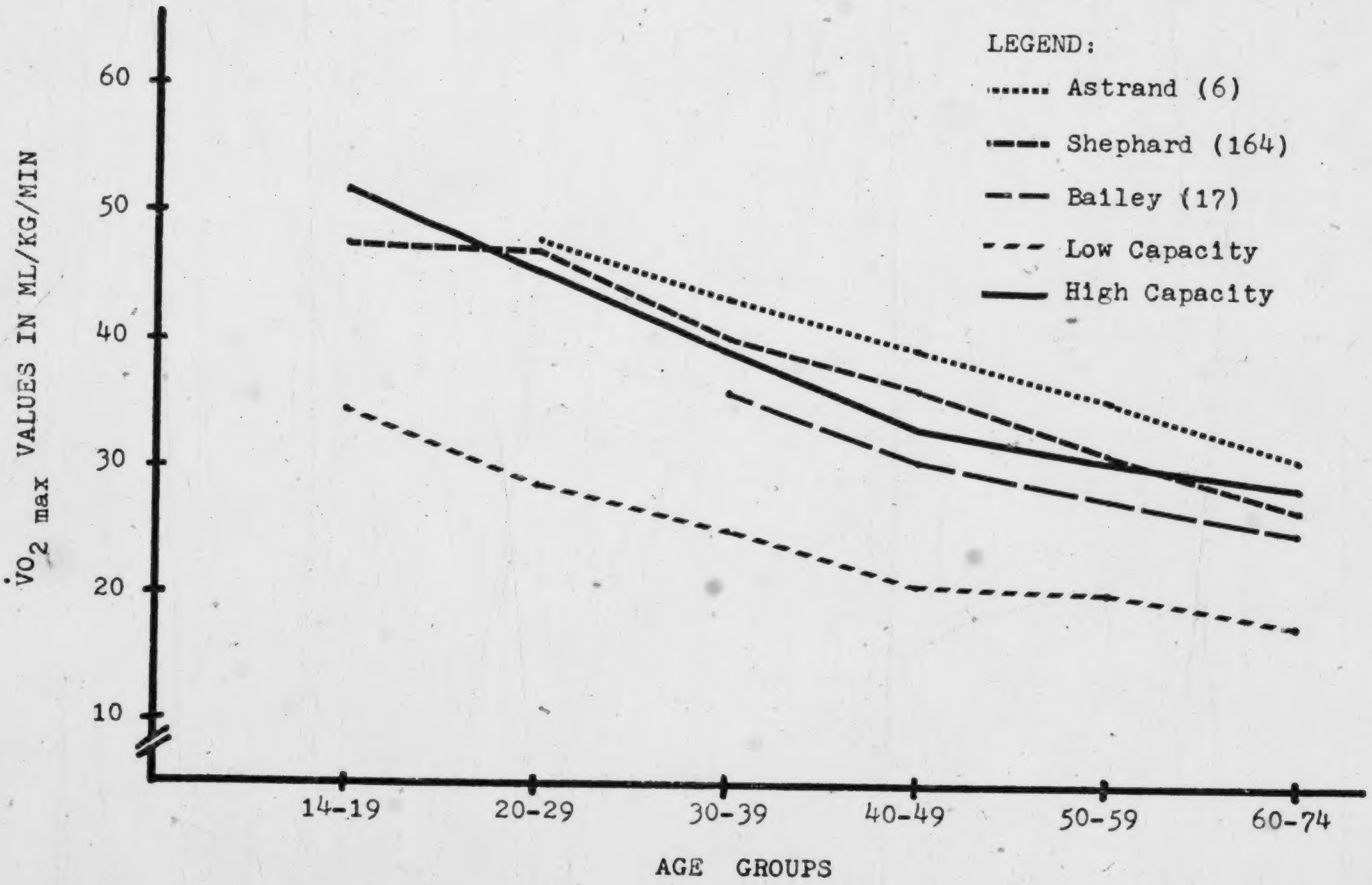


FIGURE 16: Mean $\dot{V}O_{2\ max}$ Values for Male Subjects from this Study Compared to Data from the Literature

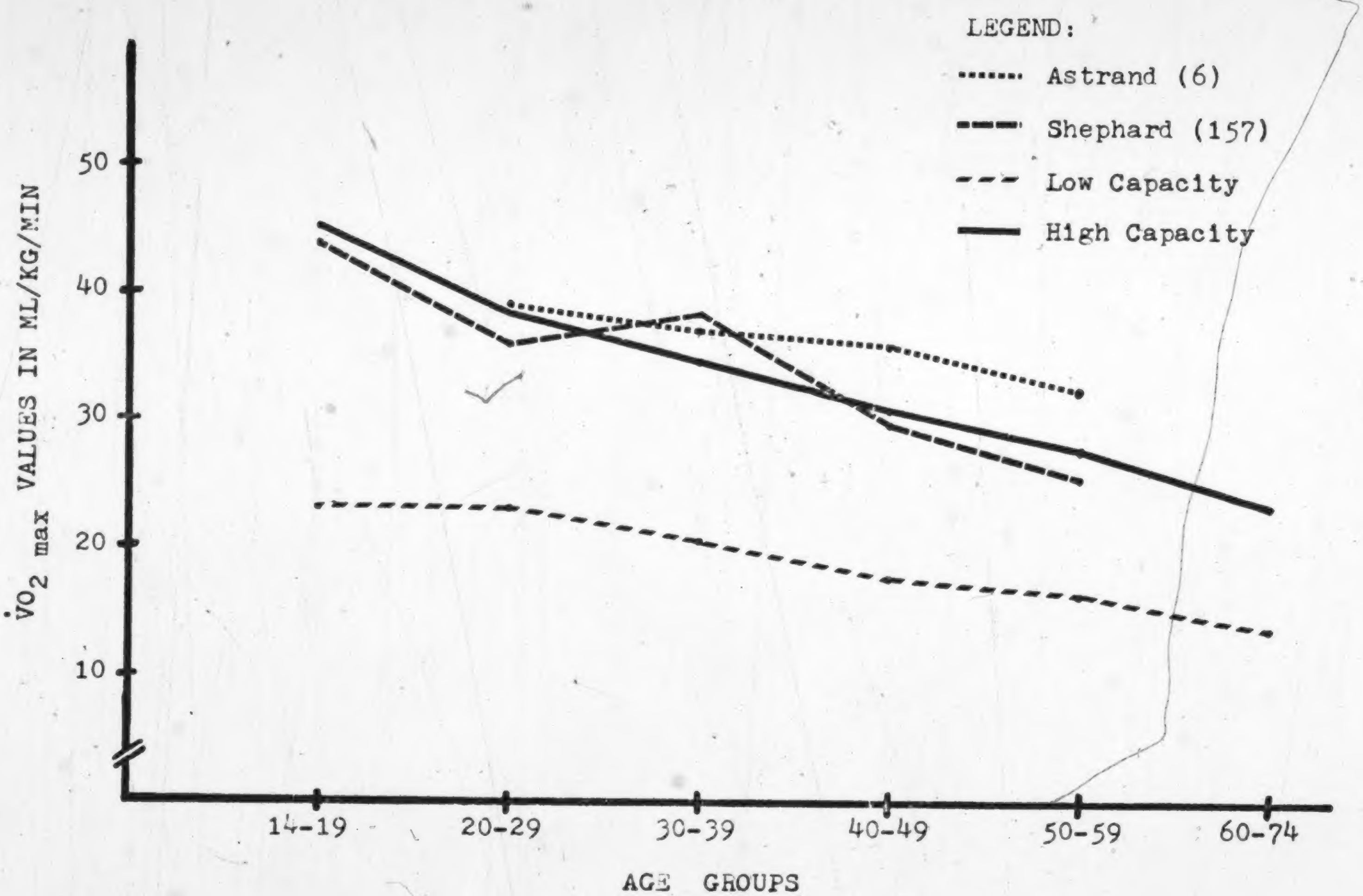


FIGURE 17: Mean $\dot{V}O_{2\ max}$ Values for Female Subjects from this Study Compared to Data from the Literature

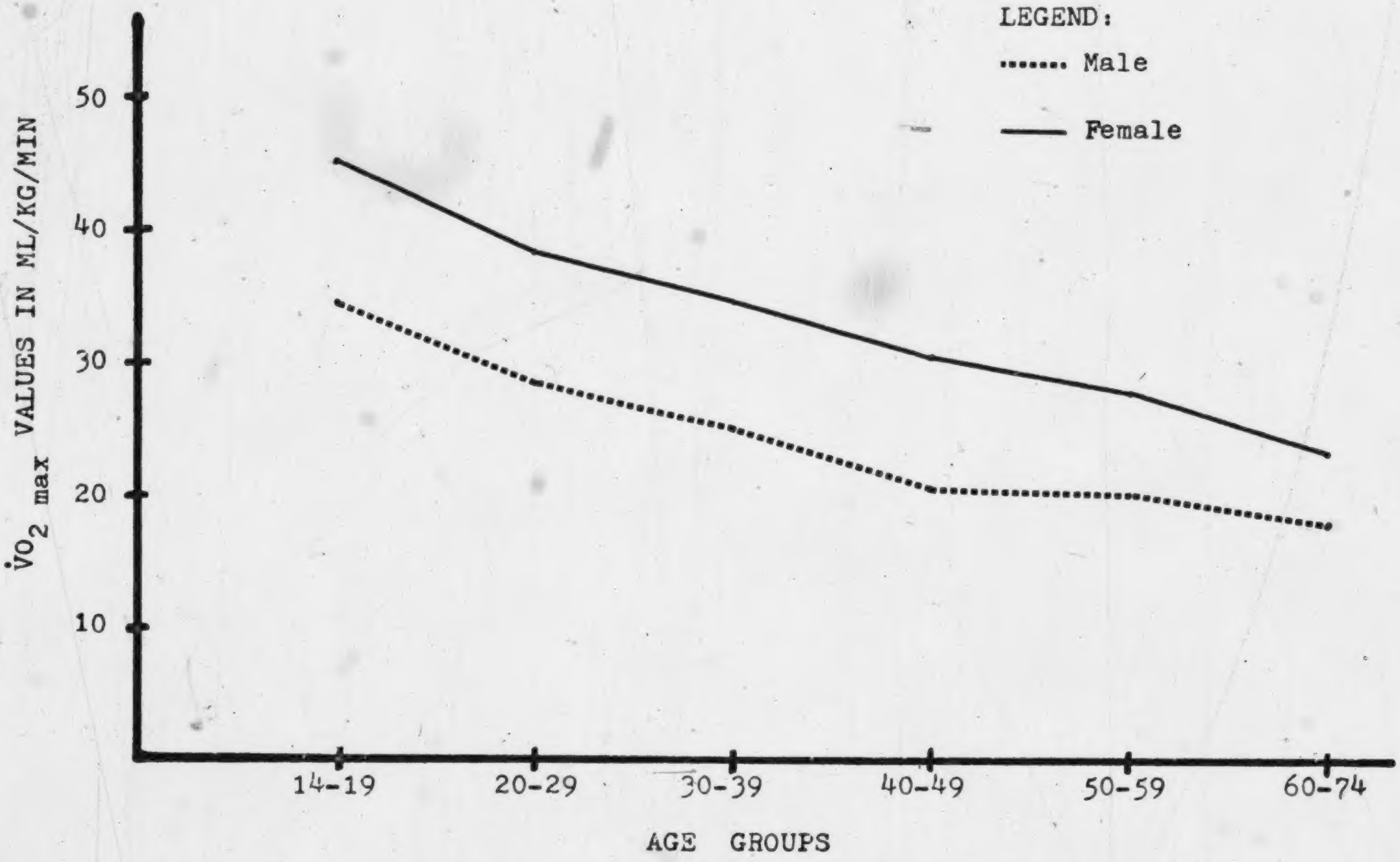


FIGURE 18: $\dot{V}O_{2\ max}$ Values for Low Aerobic Capacity Male and High Aerobic Capacity Female Subjects

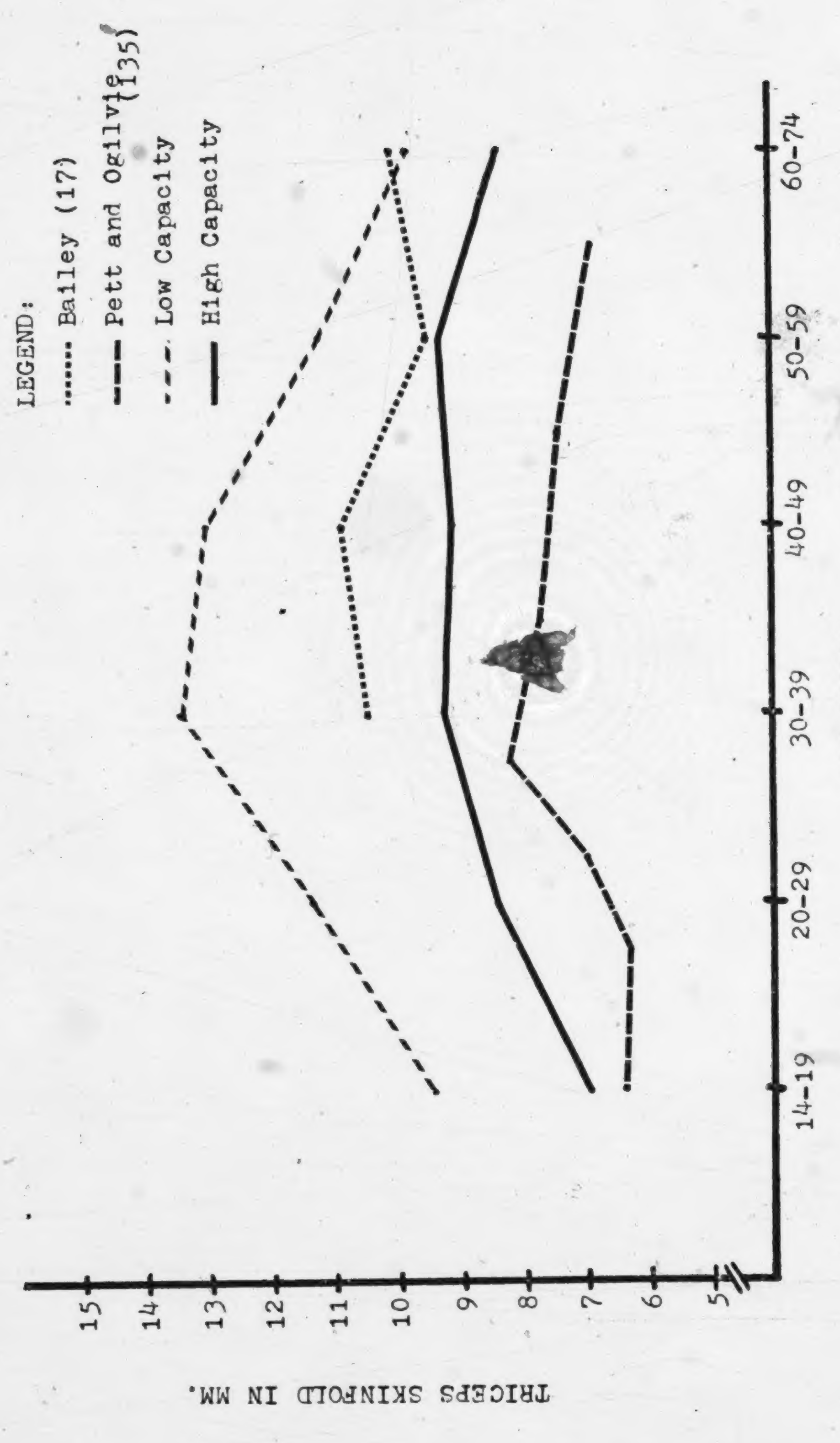


FIGURE 19: Triceps Skinfold Measures for Male Subjects from this Study Compared to Data from the Literature

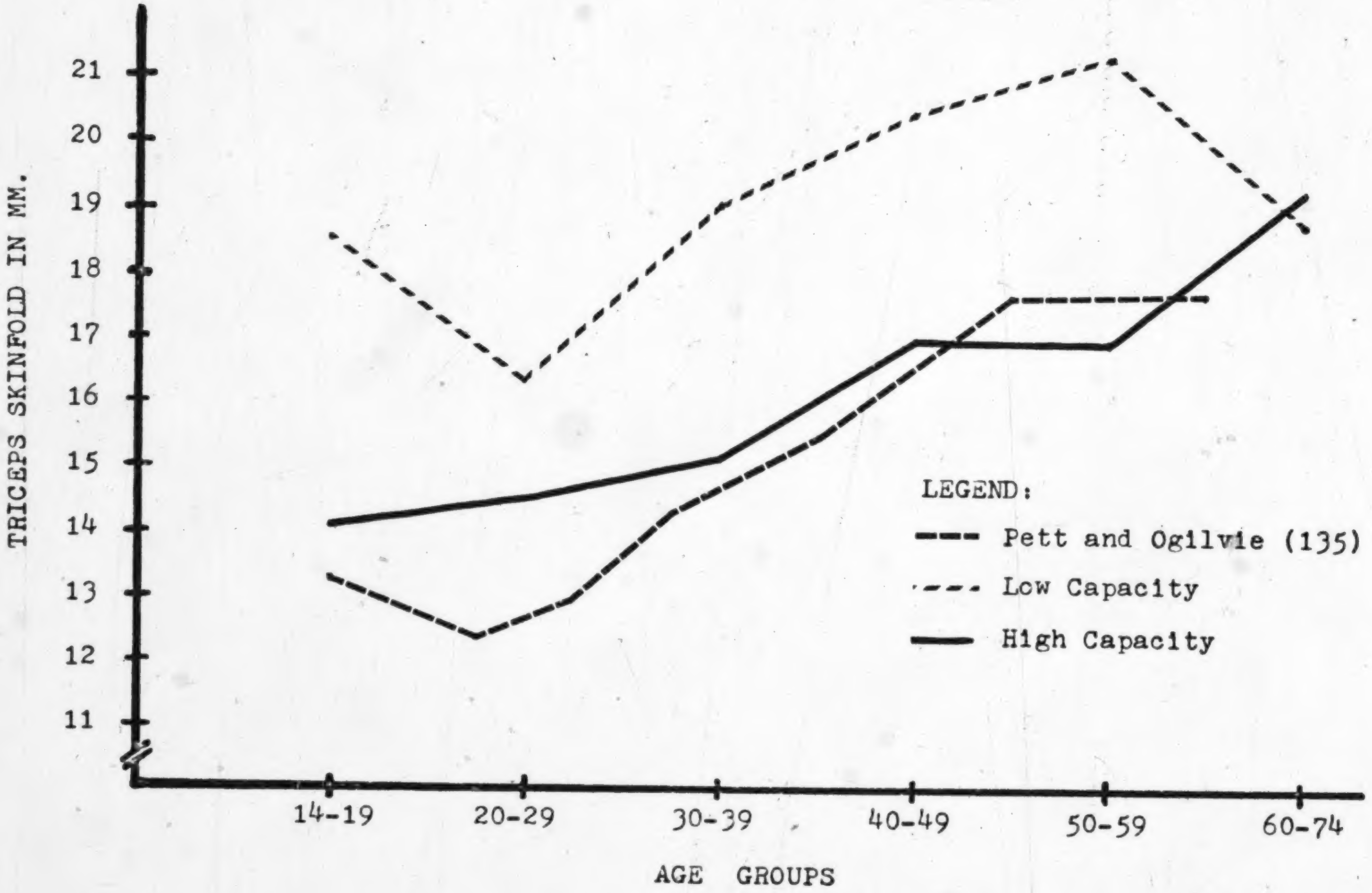


FIGURE 20: Triceps Skinfold Measures for Female Subjects from this Study Compared to Data from the Literature

The age and sex variations in triceps fat measures observed in this study are very similar to those reported in the literature. The females at every age level exhibited a higher fat measure than the male counterparts. The low aerobic capacity group males with their higher fat measures are still lower than the high aerobic capacity group females. The age trend of the triceps fat measures for males in this study is very similar to that of Pett and Ogilvie (135), Bailey (17) and in the literature generally. That is, a tendency to increase fatness from post-adolescence into middle age with decreases in body fat after approximately 55 to 60 years of age. The high aerobic capacity group did not show as marked an increase in body fat as did the low capacity group and consequently the decrease in the older age group was not as marked. The age trends for the female subjects also generally followed the data reported in the literature. One point of variation, however, is the decrease in the fat measure from the 14 to 19 year group to the 20 to 29 year group. This tendency is also observed, however, in the Pett and Ogilvie data from 1956. The general trend of increasing body fat from the 20 to 29 year group to the 50 to 59 year group is present with a levelling off at the 60 to 74 year level.

The use of the multivariate analysis to investigate the combined role of physical activity, fatness and smoking habits in differentiating high and low aerobic capacity groups has produced interesting results.

For both male and female subjects in the 50 to 59 and 60 to 74 year groups, the combined effect of these three variables as measured and analyzed in this study, does not offer an explanation to the difference between the aerobic capacity groups. A similar result was obtained in the 20 to 29 year old female group as well. Thus, while the aerobic capacity of these high and low capacity groups is significantly different, the combined effect of these three variables is not significantly different between the two groups.

For the male subjects in the first four age groups, the combined effect of the three variables is significantly different between the two aerobic capacity groups. Of the three variables, smoking habits is the variable which is least important in separating the two groups with the exception of the 20 to 29 year group. The general inconsistency of the effects of smoking that was found in the literature is present in this study as well.

Fatness as indicated by the triceps measure was the variable that accounted for the greatest amount of the difference between the two capacity groups in each of the four youngest male age categories. The use of $\dot{V}O_{2\ max}$/ kg of body weight in dividing the two groups would tend to bias the results in this direction as opposed to the use of simply the raw $\dot{V}O_{2\ max}$ in litres/minute. This effect is also increased since heavier people are in most cases fatter people (16).

The influence of physical activity in separating the two capacity groups was second highest in the 14 to 19 year, 30 to 39 and 40 to 49 year age categories and third highest in the 20 to 29 year age category. In all of the groups, the mean data shows physical activity level to be higher in the high aerobic capacity group than the low aerobic capacity group. However, when the factor used to initially create the capacity groups is $\dot{V}O_{2\ max}$ /kg of body weight fatness seems to be more important as a variable in separating the two groups. The place of smoking habits in importance in the 20 to 29 year age category requires little statistical explanation. The low aerobic capacity group contained 73.6% smokers as compared to the 25% smokers in the high capacity group. This wide variation easily explains the weight given to the smoking variable in this age group.

In the two older male groups, 50 to 59 and 60 to 74 years, mean values show that the low aerobic capacity group are both fatter and less physically active, but not significantly. The lower number of subjects in these groups would tend to decrease the power of the statistical analysis and perhaps account for some of the non-significant results obtained with these two age groups.

The three female age groups that exhibited significant differences between the capacity groups on the three combined variables revealed that physical activity and fatness are again the two variables that account for most of the separation of the two groups. In the 14 to 19 year age category activity is weighted heavier than fatness and in the other two groups fatness is weighted slightly more than physical activity. Smoking is weighted relatively low in all three groups with negative weights in the 30 to 39 and 40 to 49 year age categories which points to the greater number of smokers in the high capacity group in these age categories. The 20 to 29 year age category, while exhibiting greater activity levels and lower fatness in the high capacity group also had a higher percentage of smokers, 45% compared to 34.9% in the low capacity group which would result in a trade off statistically and an overall non- significant result.

In the two older female age groups the mean values for the three variables provide no consistent direction between the high and low capacity groups which must account for the lack of statistical significance and the inconsistent weights which were calculated. The 50 to 59 year old category shows the high capacity group to be less active, with more smokers and less fat than the low capacity group while the 60 to 74 age category shows the high capacity group to be more active, with more smokers and fatter than their low capacity counterparts. As with the men, the role of smoking as a determining variable in placing persons in a high or low aerobic capacity group appears to be of little importance.

The results of the statistical analyses between age groups confirm the generalizations that were made for both male and female data. That is, there was a significant difference between the high and low capacity groups on the three variables but that when considered individually, smoking habits were not significantly different between the high and low capacity groups but activity level and fatness were significantly different.

A significant difference between age levels on the three variables was also present in both male and female data. Lack of significant differences in any single variable between any two age groups (with the exception of activity level in the 14 to 19 year and 40 to 49 year male comparison) for both the males and females made it impossible to make specific statements about age level variation of the three variables selected.

Sex differences in $\dot{V}O_{2\ max}$ have been discussed previously in regard to mean values observed for high capacity males and females and low capacity males and females. Evaluation of the data on activity level, smoking habits and fatness between male and female subjects revealed that over all, there was a significant difference between the sexes on the three variables. The analysis showed, however, that this difference was due almost totally to differences in fatness since individual comparisons showed that smoking habits were not different between any two groups and that with the exception of the low capacity 14 to 19 year old male-female comparison, the activity levels were not different.

The role of fatness in separating the two groups was confirmed in the discriminant function analysis by the extremely high weighting of fatness relative to the other two variables. The results of the male-female comparisons are not unexpected since of the three variables, fatness is the only sex-linked variable. This data suggests that high aerobic capacity females are, generally, as active as high aerobic capacity males and that with the one exception, the low capacity females are as inactive as their male counterparts. Based on the results of this study it would appear reasonable to suggest that the most important variables that should be changed if a person wishes to improve his aerobic capacity are reduced body fat and increased physical activity. Cessation of smoking must be advised in terms of general health risk but this variable does not appear to play a large role in the determination of aerobic capacity.

The interrelationships of the three independent variables used in this study with each other and with the criterion variable ($\dot{V}O_{2\ max}$) present a very complex picture. Physical activity has been shown to affect $\dot{V}O_{2\ max}$ directly with increases up to 33% in $\dot{V}O_{2\ max}$ after a training period (147). The positive effect of increased activity on $\dot{V}O_{2\ max}$ has been demonstrated with both sexes and over a wide range (4, 15, 46, 108, 147). Increased physical activity is also positively related to decreased body fat (2, 29, 79, 149). The relationship of physical activity and smoking is not clear. Studies have shown that people who take part in activities which demand a high aerobic capacity tend not to be smokers (92), but there are many exceptions to this generalization. The above relationships appear to be present in this study as well; the high capacity groups were more active and less fat but not consistent in terms of smoking habits.

The relationship of fatness and $\dot{V}O_{2\ max}$ directly indicates that the individual with a lower percent body fat is very likely to have a higher $\dot{V}O_{2\ max}$ (ml/kg/min)(33). The relationship of physical activity and $\dot{V}O_{2\ max}$ and physical activity and fatness would also support this conclusion.

The relationship of smoking habits and fatness is quite unclear, although a University of Alberta pulmonary specialist, Dr. B. Sproule has noted an increase in body fat in dinividuals who discontinue smoking (personal communication). The results of this study might support this suggestion in that some high aerobic capacity female groups who had higher smoking scores also had lower triceps fat values. Conclusions on available evidence, however, are impossible.

The decline in overall cardio-respiratory fitness levels of Canadians in the past seven years suggested by Bailey et al. (16) is quite possibly linked to the increase in fatness which appears to have occurred over the past years as well. If, as this study suggests, fatness is as important as it appears to be in influencing aerobic capacity, then an increase in fatness will be directly related to a decrease in aerobic capacity.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

The purpose of this study was to determine the relationships and influence of physical activity level, smoking habits and fatness as they contribute to the placement of an individual in a high or low aerobic capacity group. The age and sex variations of these variables was also studied, again, with reference to high and low aerobic capacity groups.

A total of 1544 subjects representing a broad cross-section of the Saskatoon community, including 845 female and 699 male volunteer participants ranging in age from 14 to 74 years of age, made up the original sample. As a result of screening by questionnaire and an exercise test, 1230 of these subjects returned to the test center to perform the bicycle ergometer test which provided the basic data for this study.

A prediction of $\dot{V}O_{2\ max}$ by use of the Astrand submaximal bicycle ergometer test and the Astrand-Ryhming nomogram was made for each of the 1230 subjects. As well, a measure of triceps skinfold was made and information on each subject's smoking habits and a self-rating of physical activity level were gathered.

Subjects were divided into high, medium or low aerobic capacity groups on the basis of the predicted $\dot{V}O_{2\ max}$ score (ml/kg/min). The medium group was ignored so that extreme aerobic capacity groups were created. An analysis of variance was performed to determine if the high and low aerobic capacity groups were in fact significantly different. The results of that analysis showed that the high and low aerobic capacity groups for each age and sex grouping were indeed significantly different ($p < 0.01$).

Mean values for $\dot{V}O_{2\ max}$ were compared to values reported in the literature. It was concluded, for males, that the high aerobic capacity group from this study was quite similar at each age level to data reported by Shephard (164) on Canadian subjects, by Bailey (17) on rural Manitoba males and by Astrand (6) on Swedish subjects. The low aerobic capacity group were substantially below these levels for each age group. The comparisons of the female data showed that the high aerobic capacity group were quite similar at each age level to data published by Shephard (157) and Astrand (6). Again, the low capacity groups were substantially lower at each age level than the other data reported. A consistent decrease in $\dot{V}O_{2\ max}$ from the younger age groups to the older was observed and at each age level the mean values for male subjects were higher than those for female subjects. An overlap of male-female values was noted when the high and low classifications were compared. The high aerobic capacity female groups were consistently higher at each age level than the corresponding low aerobic capacity male groups.

Both male and female subjects in the high aerobic capacity group tended to be more physically active than their age corresponding counterparts in the low aerobic capacity groups. For male subjects the most active age group was the youngest with consistent decreases for older age groups with age group six (60 to 74 years) being the lowest. The females did not exhibit consistent age changes in physical activity with age group 1 (14 to 19 years) and age group 6 (60 to 74 years) being the most active.

Generally, the male high aerobic capacity group had fewer smokers than the low aerobic capacity group. However, age group 3 (30 to 39 years) had equal numbers of smokers in high and low capacity groups and age group 5 (50 to 59 years) had more smokers in the higher aerobic capacity group. More female subjects in the high aerobic capacity group, however, were smokers than in the low capacity group. Only age group 1 (14 to 19 years) did not exhibit this result.

The data on triceps fat revealed that the low aerobic capacity subjects are fatter than the high aerobic capacity group. Comparisons for triceps skinfold measures between data from this study and the Canadian Height-Weight Survey of 1956 were made. This 1956 data shows lower skinfold measures at all age groups than the high aerobic capacity group from this study for male subjects and for all age groups except approximately the 50 to 60 year age group for females. Thus, the suggestion that Canadians have become fatter in the intervening seventeen years since the earlier survey seems appropriate. Females had higher skinfold measures than the males at each age level and general age trend in fatness reported in the literature was also observed. That is, for males, a general tendency for younger people to have lower body fat with increases through middle age and a decrease in older age. Female data showed similar age trends to data in the literature with the exception of age group 1 (14 to 19 years) in which skinfold measures were higher.

The analysis of the combined effect of the three variables in differentiating the high and low aerobic capacity groups showed significant differences between the capacity groups for males and females in age groups 1 (14 to 19 years), 3 (30 to 39 years) and 4 (40 to 49 years) and males in age group 2 (20 to 29 years). The combined effect of physical activity level, smoking habits and fatness was not significantly different between high and low aerobic capacity for age group 2 (20 to 29 years) females and age group 5 (50 to 59 years) and 6 (60 to 74 years) males and females. In those groups in which significant differences for the combined variables were produced analysis to determine the place of each of the variables causing this difference was performed. Generally, smoking was the least important variable with fatness and activity level being most important. For the male groups fatness was the heaviest weighted variable in each age group. Physical activity was the second heaviest weight in each but age group 2 (20 to 29 years). For the female subjects fatness was weighted heaviest in age groups 3 (30 to 39 years) and 4 (40 to 49 years) and second in age group 1 (14 to 19 years). Physical activity was weighted second in age groups 3 (30 to 39 years) and 4 (40 to 49 years) and first in age group 1 (14 to 19 years).

Statistical analysis between age groups confirmed these findings in that a significant difference between high and low aerobic capacity groups on the combined variables was obtained. Individual contrasts revealed significant differences between the capacity groups for physical activity and fatness but not for smoking.

An overall significant difference on the combined variables over the age group range was also obtained for both the male and female data. Individual comparisons provided no significant differences on any individual variable at any age level for the female data and only one significant contrast for male data. That difference was a significantly higher activity level in age group 1 (14 to 19 years) males than in age group 4 (40 to 49 years) males.

Statistical analysis between sexes showed an overall significant difference between males and females on the three combined variables. Individual comparisons revealed significant differences for fatness between males and females at each age level and for each aerobic capacity group. There was only one significant difference in activity level (age group 1, low aerobic capacity) and no significant differences in smoking habits at any age level or capacity group. Thus, the overall difference can be attributed almost totally to the difference in fatness between the sexes.

CONCLUSIONS

Within the limitations of this study, the following conclusions appear to be justified:

1. The combined effect of physical activity level, smoking habits and fatness is significantly different between high and low aerobic capacity groups in age groups 1 (14 to 19 years), 3 (30 to 39 years) and 4 (40 to 49 years) male and female subjects and in age group 2 (20 to 29 years) male subjects.

2. The combined effect of physical activity level, smoking habits and fatness is not significantly different between high and low aerobic capacity groups in age group 2 (20 to 29 years) female subjects, age group 5 (50 to 59 years) male and female subjects and age group 6 (60 to 74 years) male and female subjects.

3. Fatness is the most important variable in differentiating high and low aerobic capacity groups in each of the male groups included in 1 above.

4. Physical activity level is the second most important variable differentiating aerobic capacity groups in three of the four male groups from 1 above.

5. Smoking habit is the least important variable differentiating aerobic capacity groups in three of the four male groups from 1 above.

6. Smoking habit is the least important variable differentiating aerobic capacity groups in all three of the female groups from 1 above.

7. Fatness was the most important variable in differentiating high and low aerobic capacity groups in female age groups 3 (30 to 39) and 4 (40 to 49) from 1 above.

8. Physical activity level was the second most important variable differentiating aerobic capacity groups in female age groups 3 (30 to 39 years) and 4 (40 to 49 years) and the most important in female age group one (14 to 19 years) from 1 above.

9. For male subjects considered in total the combined effects of physical activity level, smoking habits and fatness is significantly different between high and low aerobic capacity groups. Consideration of the variables individually in this context shows that smoking is not significantly different between high and low capacity groups but physical activity levels and fatness are significantly different.

10. For female subjects considered in total the combined effect of physical activity level, smoking habits

and fatness is significantly different between high and low aerobic capacity groups. Consideration of the variables individually in this context shows that smoking is not significantly different between high and low aerobic capacity groups but physical activity levels and fatness are significantly different.

11. There is an overall significant difference in physical activity level, smoking habits and fatness between the six age groups for both male and female subjects. There are no consistent individual age group differences that explain this overall difference, however.

12. High aerobic capacity males have significantly higher $\dot{V}O_{2\ max}$ values at all age groups than high aerobic capacity females.

13. Low aerobic capacity males have significantly higher $\dot{V}O_{2\ max}$ values at all age groups than low aerobic capacity females.

14. High aerobic capacity male and female subjects are significantly different from each other at each age level on the combined effect of physical activity level, smoking habits and fatness. Individual comparisons of the variables show that high aerobic capacity males and females are not significantly different in physical activity levels or smoking habits but are significantly different in fatness.

15. Low aerobic capacity male and female subjects are significantly different from each other at each level on the combined effect of physical activity level, smoking

habits and fatness. Individual comparisons of the variables show that males and females are significantly different in fatness at all age levels and in physical activity level at age group 1 (14 to 19 years) but not significantly different in physical activity level at any other age level and not significantly different in smoking habits at any age level.

16. The most important variable in separating high aerobic capacity males and females is fatness with physical activity level and smoking habits being relatively unimportant.

17. The most important variable in separating low aerobic capacity males and females is also fatness with physical activity level and smoking habits being relatively unimportant.

Although none of the following observations have been tested statistically, they still would appear to be worthy of note:

1. The high aerobic capacity male and female groups in this study are very similar in $\dot{V}O_{2\ max}$ to earlier Canadian results and Swedish results. The low aerobic capacity groups are substantially lower than these groups.

2. High aerobic capacity females exhibit higher $\dot{V}O_{2\ max}$ values than low aerobic capacity males at all age levels.

3. High aerobic capacity male and female subjects are more physically active than their low aerobic capacity counterparts.

4. The male high aerobic capacity groups have fewer smokers than the low capacity groups.

5. The female high aerobic capacity groups have more smokers than the low aerobic capacity groups.

6. Male and female subjects included in this study are fatter than Canadian subjects surveyed in 1956.

7. The male high aerobic capacity groups exhibit a lower triceps skinfold measure at all age groups than their low aerobic capacity counterparts.

8. The female high aerobic capacity groups generally exhibit a lower skinfold measure than the low aerobic capacity groups.

RECOMMENDATIONS FOR FURTHER RESEARCH

1. Studies to determine the effect of fitness testing programs in terms of educational value and motivation to improve or maintain existing personal fitness levels. This recommendation appears to be warranted, particularily when federal government programs are presently advocating the institution of mass fitness testing centres across Canada.

2. Studies to determine the effectiveness of mass physical activity participation promotional programs which have been instituted in a number of areas in Canada and

throughout the world.

3. Longitudinal studies to investigate at what point in life the variables that determine aerobic capacity become fixed if in fact they do become fixed.

4. Studies of the effectiveness of various types of physical activity and/or educational programs in the creation of long term activity patterns in the participants.

REFERENCES

1. Allen, T.H., M.T. Peng, K.P. Chen, T.F. Huang and H.S. Fang, "Predicting Total Adiposity from Skinfolds and the Curvilinear Relationship Between External and Internal Adiposity," Metabolism, 5: 346-352, 1956.

2. Andersen, K.L. and L. Hermansen, "Aerobic Working Capacity in Middle Aged Norwegian Men," Journal of Applied Physiology, 20: 432-496, 1965.

3. Andersen, K.L., "Work Capacity of Selected Populations", in The Biology of Human Adaptibility edited by P.T. Baker and J.S. Weiner, Oxford: Clarendon Press, 1966, pp. 67-90.

4. Andersen, K.L., "Commentary," Canadian Meidcal Association Journal, 96: 841-842, 1967

5. Astrand, I., "The Physical Work Capacity of Workers 50 to 64 Years Old," Acta Physiologica Scandinavica, 42: 73-86, 1958.

6. Astrand, I., "Aerobic Working Capacity in Men and Women with Special Reference to Age," Acta Physiologica Scandinavica, 49 (Supp 169): 45-60, 1960.

7. Astrand, I., "Aerobic Work Capacity - Its Relation to Age, Sex and Other Factors," Circulation Research, 20 (Supp 1): I 211- I 217, March, 1967.

8. Astrand, P.O., "Human Physical Fitness with Special Reference to Sex and Age," Physiological Reviews, 36: 309-335, 1956.

9. Astrand, P.O., "Measurement of Maximal Oxygen Uptake," Canadian Medical Association Journal, 96: 732-734, 1967.

10. Astrand, P.O., "Physical Performance as a Function of Age," Journal of the American Medical Association, 205: 729-733, 1968.

11. Astrand, P.O., Work Tests with the Bicycle Ergometer, Varberg Sweden: Monark-Crescent AB.

12. Astrand, P.O., Health and Fitness, Stockholm, Sweden: Universaltryck, 1972.

13. Astrand, P.O. and I. Ryhming, "A Nomogram for Calculation of Aerobic Capacity (Physical Fitness) from Pulse Rate during Submaximal Work," Journal of Applied Physiology, 7: 218-221, 1954.

14. Astrand, P.O. and B. Saltin, "Oxygen Uptake During the First Minute of Heavy Muscular Exercise," Journal of Applied Physiology, 16: 971-976, 1961 (B).

15. Astrand, P.O. and K. Rodahl, *Textbook of Work Physiology*, New York: McGraw-Hill Book Company, 1970.

16. Bailey, D.A., R.J. Shephard, R.L. Mirwald, and G.A. McBride, "A Current View of Cardiorespiratory Fitness Levels of Canadians," presentation to First Canadian Congress for the Multidisciplinary Study of Sport and Physical Activity, Montreal, 1973.

17. Bailey, G.E., "Fitness Levels of a Rural Population Aged 30 to 85," Unpublished Masters thesis, University of Alberta, Edmonton, 1972.

18. Bany, A.J., J.W. Daley, E.D. Pruitt, J.R. Steinmetz, H.F. Page, N.C. Birkhead, and K. Rodahl, "The Effects of Physical Conditioning on Older Individuals' Work Capacity, Circulatory-Respiratory Functions and Work E.C.G.," Journal of Gerontology, 21: 182-199, 1966.

19. Barter, J. and G.B. Forbes, "Correlation of Potassium^{40} Data with Anthropometric Measurements," Annals of New York Academy of Science, 110: 264-270, 1963.

20. Baycroft, G.H., "An Evaluation of the Modified Astrand-Ryhming Nomogram as an Estimation of Maximum Oxygen Comsumption," Unpublished Masters thesis, University of Alberta, 1964.

21. Behnke, A.R., B.G. Feen, and W.E. Welham, "The Specific Gravity of Healthy Men, Body Weight: Volume as an Index of Obesity," Journal of American Medical Association, 118: 495-498, 1942.

22. Behnke, A.R., E.F. Osserman and W.C. Welham, "Lean Body Mass," Archives of Internal Medicine, 91: 585-601, 1953.

23. Behnke, A.R. and J.H. Wilmore, *Evaluation and Regulation of Body Build and Compostion*, Englewood Cliffs, Calif.: Prentice-Hall, Inc., 1974.

24. Best, W., "An Improved Caliper for Measurement of Skinfold Thickness," Journal of Laboratory and Clinical Medicine, 43: 967-970, 1954.

25. Blackburn, H., J. Brozek and H.L. Taylor, "Common Circulatory Measures in Smokers and Non-smokers," Circulation, 22: 1112-1124, 1960.

26. Booth, R.A.D., B.A. Goddard, and A. Paton, "Measurement of Fat Thickness in Man: A Comparison of Ultrasound, Harpenden Calipers and Electrical Conductivity," British Journal of Nutrition, 20: 719-725, 1966.

27. Brozek, J., "Physique and Nutritional Status in Adult Man," Human Biology, 28: 124-139, 1956.

28. Brozek, J. and A. Keys, "The Evaluation of Leanness-Fatness in Man: Norms and Inter-relatioships," British Journal of Nutrition, 5: 194-206, 1951.

29. Brozek, J. and A. Keys, "Relative Body Weight, Age and Fatness," Geriatrics, 8: 70-75, 1953.

30. Brozek, J., F. Grande, J.T. Anderson, and A. Keys, "Densitometric Analysis of Body Composition: Revison of Some Quantitative Assumptions," Annals of the New York Academy of Science, 110: 113-140, 1963.

31. Brozek, J., K. Kihlberg, H.L. Taylor and A. Keys, "Skinfold Distributions in Middle Aged American Men: A Contribution to Leanness-Fatness," Annals of the New York Academy of Science, 110: 492- 502, 1963.

32. Brunner, P., and G. Manelis, "Myocardial Infarction Among Memebers of Communal Settlements in Israel," Lancet, 2: 1049-1050, 1960.

33. Buskirk, E. and H.L. Taylor, "Maximal Oxygen Intake and Its Relation to Body Composition With Special Reference to Chronic Physical Activity and Obesity," Journal of Applied Physiology, 11: 72-78, 1957.

34. Buskirk, E.R., D. Harris, J. Mendez and J. Skinner, "A Comparison of Two Assessments of Physical Activity and a Survey Method for Caloric Intake," The American Journal of Clinical Nutrition, 24: 1119-1125, 1971.

35. Canada Department of National Health and Welfare, Canadian Study of Health and Smoking, Ottawa: Queen's Printer, 1966.

36. Canadian Heart Foundation, Heart Disease in Canada, The Canadian Heart Foundation, 1974.

37. Chen, K.P., A. Damon and O. Elliot, "Body Form, Composition and Some Physiological Functions of Chinese on Taiwan," Annals of New York Academy of Science, 110: 760-777, 1963.

38. Chevalier, R.B., J.A. Bowers, S. Bondurant and J.C. Ross, "Circulatory and Ventilatory Effects of Exercise in Smokers and Non-smokers," Journal of Applied Physiology, 18: 357-360, 1963.

39. Chirico, A.M. and A.J. Stunkard, "Physical Activity and Human Obesity," New England Journal of Medicine, 263: 935-940, 1960.

40. Cooley, W.W. and P.R. Lohnes, *Multivariate Procedures for the Behavioral Sciences*, New York: John Wiley and Sons, Inc., 1962.

41. Cooper, K.H., G.O. Grey and R.A. Bottenberg, "Effects of Cigarette Smoking on Endurance Performance," Journal of American Medical Association, 203: 123-126, 1968.

42. Costill, D.L., H. Thomason and E. Roberts, "Fractional Utilization of the Aerobic Capacity During Distance Running," Medicine and Science in Sports, 5 (4) 248-252, 1973.

43. Cotes, J.E., C.T.M. Davies, O.G. Edholm, M.J.R. Healy and J.M. Tanner, "Factors Relating to the Aerobic Capacity of 46 Healthy British Males and Females, Ages 18 to 28 years," Proceedings of the Royal Society of Britain, 174: 91-114, 1969.

44. Cotton, S.G., J.M. Nixon, R.G. Carpenter and D.W. Evans, "Factors Discriminating Men With Coronary Heart Disease from Healthy Controls," British Heart Journal, 34: 458-464, 1972.

45. Crook, G.H., C.A. Bennett, W.O. Normwood and J.A. Mahaffey, "Evaluations of Skinfold Measurements and Weight Chart to Measure Body Fat," Journal of the American Medical Association, 198: 39-44, 1966.

46. Cumming, G.R., "Current Levels of Fitness", Canadian Medical Association Journal, 96: 868-877, 1967.

47. Cunningham, D.A., H.J. Montoye, H.L. Metzner, and J.B. Keller, "Physical Activity at Work and Active Leisure as Related to Occupation," Medicine and Science in Sports, 1: 165-170, 1969.

48. Davies, C.T.M., "Maximum Oxygen Uptake: Predicted from Cardiac Frequency During Submaximal Exercise," Journal of Physiology, 189: 77-78, January, 1967.

49. Davies, C.T., "Determinants of Maximum Aerobic Power in Relation to Age," Journal of Physiology (London), 197: Communications 76P, 1968.

50. Davies, C.T.M., "Limitations to the Prediction of Maximum Oxygen Intake from Cardiac Frequency Measurements," Journal of Applied Physiology, 24: 700-706, 1968.

51. Davies, C.T.M., "Measuring the Fitness of a Population," Proceedings of the Royal Society of Medicine, 62: 1171-1174, 1969.

52. Davies, C.T.M., J.E. Cotes and C. John, "Relationship of Oxygen Uptake, Ventilation and Cardiac Frequency to Body Weight During Different Forms of Standardized Exercise," Journal of Physiology, 190: 29P-30P, 1967.

53. Dawson, P.M. and F.A.Hellebrandt, "The Influence of Aging in Man Upon his Capacity for Physical Work and Upon his Cardio-vascular Responses to Exercise," American Journal of Physiology, 143: 420-427, 1945.

54. deVries, H.A., "Physiological Effects of an Exercise Training Regimen Upon men Aged 52 to 88," Journal of Gerontology, 25(4): 325-336, 1970.

55. Dill, D.B., "The Influence of Age on Performance as Shown by Exercise Tests," Pediatrics, 32: 737-741, 1963.

56. Dill, D.B., S. Horvath and D. Craig, "Responses to Exercise as Related to Age," Journal of Applied Physiology, 12: 195-196, 1958.

57. Dill, D.B. and F.C. Consalazio, "Responses to Exercise as Related to Age and Environmental Temperature," Journal of Applied Physiology, 17: 645-649, 1962.

58. Durnin, J.V.G.A. and R. Passmore, Energy, Work and Leisure, London: Heineman Education Books Ltd., 1967.

59. Durnin , J.V.G.A. and M.M.Rahaman, "The Assessment of the Amount of Fat in the Human Body from Measurements of Skinfold Thicknesses," British Journal of Nutrition, 21: 681-689, 1967.

60. Edwards, D.A.W., "Differences in the Distribution of Subcutaneous Fat with Sex and Maturity," Clinical Science, 10: 305, 1951.

61. Edwards, D.A.W., W.H. Hammond, M.J. Healy, J.M. Tanner and R.H.Whitehouse, "Design and Accuracy of Calipers for Measuring Subcutaneous Tissue Thickness," British Journal of Nutrition, 9: 133-144, 1955.

62. Ekblom, B., "Effects of Physical Training on the Oxygen Transport System in Man," Acta Physiologica Scandinavica, Supp 328, 1969.

63. Ekblom, B., "Effect of Physical Training in Adolescent Boys," Journal of Applied Physiology, 27: 350-355, 1969.

64. Epstein, F.H., "Multiple Risk Factors and the Prediction of Coronary Heart Disease," Bulletin of New York Academy of Medicine, 44: 916-935, 1968.

65. Eriksson, B.O. and G. Koch, "Effects of Physical Training on Hemodynamic Response During Submaximal and Maximal Exercise in 11-13 Year old Boys," Acta Physiologica Scandinavica, 87: 27-39, 1973.

66. Falkner, F., "An Air Displacement Method of Measuring Body Volume in Babies: A Preliminary Communication," Annals of the New York Academy of Science, 110: 75-79, 1963.

67. Fletcher, R.F., "The Measurement of Total Body Fat with Skin Calipers," Clinical Science, 22: 333-346, 1962.

68. Forbes, G.B. and J.B. Hursh, "Age and Sex Trends in Lean Body Mass Calculated from K^{40} measurements: With a note on the Theoretical Basis for the Procedure," Annals of the New York Academy of Science, 110: 255-263, 1963.

69. Fox, F.M. and J.S. Skinner, "Physical Activity and Cardiovascular Health," American Journal of Cardiology, 14: 731-746, 1964.

70. Fox, S.M., J.P. Naughton and W.L. Haskell, "Physical Activity and the Prevention of Coronary Heart Disease," Annals of Clinical Research, 3: 404-432, 1971.

71. Fox, E.L., C.E. Billings, R.L. Bartels, R. Bason and D. Mathews, "Fitness Standards for Male College Students," Inernationale Zeitschrift fuer Angewandte Physiologie, 31: 231-236, 1973.

72. Frank, C.W. and E. Weinblatt, "Physical Inactivity as a Lethal Factor in Myocardial Infarction Among Men," Circulation, 34: 432-438, August, 1968.

73. Franks, B. Don, "Smoking and Selected Cardiovascular-Respiratory Measures," The Research Quarterly, 41 (2): 140-144, 1970.

74. Franzen, R., Physical Measures of Growth and Nutrition, New York: American Child Health Association, 1929.

75. Frick, M.H., A. Konttinen and H.S.S. Sarjas,"Effects of Physical Training on Circulation at rest and During Exercise," American Journal of Cardiology, 12: 142-147, 1963.

76. Glassford, R.G., G.H.Y. Baycroft, A.W. Sedgewick and R.B.J. Macnab, "Comparison of Maximal Oxygen Uptake Values by Predicted and Actual Methods," Journal of Applied Physiology, 20: 509-513, 1965.

77. Glassford, R.G. and M.L. Howell, "Smoking and Physical Fitness: a Preliminary Report," Canadian Family Physician, 60-69, October, 1969.

78. Greene, J.A., "Clinical Study of the Etiology of Obesity," Annals of Internal Medicine, 12: 1797-1803, 1939.

79. Grimby, G. and B. Saltin, "Physiological Analysis of Physically Well Trained Middle Aged and Old Athletes," Acta Medica Scandinavica, 179: 513-526, 1966.

80. Hansen, J.S., M.D. Burton, S. Tabakin and A.M. Levey, "Comparative Exercise: Cardiorespiratory Performance of Normal Men in the third, fourth and fifth Decades of Life," Circulation, 37: 345-359, 1968.

81. Hartley, L.H., G. Grimby, A. Kilbom, N.J. Nilsson, I. Astrand, J. Bjure, B. Ekblom and B. Saltin, "Physical Training in Sedentary Middle Aged and Older Men," Scandinavian Journal of Clinical Laboratory Investigation, 24: 335-344, 1969.

82. Heald, F.P., E.E. Hunt, R. Schwartz, C.D. Cook O. Elliot and B. Vajda, "Measures of Body Fat and Hydration in Adolescent Boys," Pediatrics, 31: 226-2239, 1963.

83. Heinila, K., M.J. Karvonen, and A. Koskela, Assessment of Habitual Physical Activity, Helsinki, Finland: Institute of Occupational Health, January 1965.

84. Henry, F.M. and J.R. Fitzhenry, "Oxygen Metabolism of Moderate Exercise with Some Observations on the Effects of Tobacco Smoking," Journal of Applied Physiology, 2: 464-468, 1950.

85. Hermansen, L. and K.L. Andersen, "Aerobic Work Capacity in Young Norweigian Men and Women," Journal of Applied Physiology, 20: 425-431, 1965.

86. Hettinger, T., N.C. Birkhead, S.M. Horvath, B. Issekutz, and K. Rodahl, "Assessment of Physical Work Capacity," Journal of Applied Physiology, 16: 153-156, 1961.

87. Hill, A.V., C.N.H. Long and H. Lupton, "Muscular Exercise, Lactic Acid and the Supply and Utilization of Oxygen," Proceedings of the Royal Society of London (Biology), 97: 155-176, 1925.

88. Hyde, R.C., "The Astrand-Ryhming Nomogram as a Predictor of Aerobic Capacity for Secondary School Students," Unpulished Masters thesis, University of Alberta, 1965.

89. Ishiko, T., "Aerobic Capacity and External Criteria of Performance," Canadian Medical Association Journal, 96: 746-749, 1967.

90. Ismail, A.H., H.B. Falls and D.F. MacLeod, "Developments of a Criterion for Physical Fitness tests from Factor Analysis Results," Journal of Applied Physiology, 20: 991-999, 1965.

91. Issekutz, B., N.C. Birkhead and K. Rodahl, "Use of Respiratory Quotients in Assessment of Aerobic Work Capacity," Journal of Applied Physiology, 17: 47-50, 1962.

92. Journal of the American Medical Association Reviews, "Effect of Smoking on Performance,", Journal of the American Medical Association, 170: 1106, 1959.

93. Jokl, E., "Physical Activity and Body Composition: Fitness and Fatness," Annals of New York Academy of Science, 110: 778-794, 1963.

94. Juurup, A. and L. Muido, "On Acute Effects of Cigarette Smoking on Oxygen Consumption, Pulse Rate, Breathing Rate and Blood Pressure in Working Organism," Acta Physiologica Scandinavica, 11: 48-60, 1946.

95. Kannel, W.B., "Habitual Level of Physical Activity and the Risk of Coronary Artery Disease: The Framingham Study," Canadian Medical Association Journal, 96: 811-812, 1967.

96. Kannel, W.B., P. Sorlie and P. McNamara, *Coronary Heart Disease and Physical Fitness*, edited by D.A. Larsen and R.D. Malmborg, Copenhagen: Munksgaard, 1971, p.256.

97. Kay, H. and P.V. Karpovich, "Effect of Smoking on the Recuperation from Local Muscular Fatigue," Research Quarterly, 20: 250-256, 1949.

98. Keys, A. and J. Brozek, "Body Fat in Adult Man," Physiological Reviews, 33: 245-325, 1953.

99. Kleinbaum, D.G., L.L. Kupper, J.C. Cassel, and H. A. Trylor,"Multivariate Analysis of Risk of Coronary Heart Disease in Evans County, Georgia," Archives of Internal Medicine, 128: 943-948, 1971.

100. Knuttgen, H.G., " Aerobic Capacity of Adolescents," Journal of Applied Physiology, 22: 655-658, 1967.

101. Krumholz, R.A., R.B. Chavalier and J.C. Ross, "Cardiopulmonary Function in Young Smokers," Annals of Internal Medicine, 60: 603-610, 1964.

102. Krumholz, R.A., R.B. Chevalier and J.C. Ross, "Changes in Cardio-pulmonary Functions Related to Abstinence from Smoking," Annals of Internal Medicine, 62: 197-207, 1965.

103. Lalonde, M., A New Perspective on the Health of Canadians, Ottawa: Government of Canada, April, 1974.

104. Larsen, P.S., H.B. Haag and H. Silvette, Tobacco, Baltimore: The Williams and Wilkins Co., 1961.

105. Lesser, G.T. and G. Zak, "Measurement of Total Body Fat in Man by the Simultaneous Absorption of two Inert Gases," Annals of New York Academy of Science, 110: 40-54, 1963.

106. Lew, E.A., "High Blood Pressure, Other Risk Factors and Longevity: The Insurance Viewpoint," American Journal of Medicine, 55: 281-294, 1973.

107. Luft, V.C., D. Cardus, T.P.K. Lim, E.C. Anderson and J.L. Horvath, "Physical Performance in Relation to Body Size and Composition," Annals of the New York Academy of Science, 110: 795-808, 1963.

108. McDonough, J.R., F. Kusumi and R.A.Bruce, "Variations in Maximal Oxygen Intake with Physical Activity in Middle Aged Men," Circulation, 41: 743-751, 1970.

109. Macnab, R.B.J., "Commentary," Canadian Medical Association Journal, 96 (12): 750, March 67.

110. Macnab, R.B.J., P.R. Conger and P.S. Taylor, "Differences in Maximal and Submaximal Work Capacity in Men and Women," Journal of Applied Physiology, 27(5): 644-648, 1969.

111. Mann, G.V., H.L. Garrett and A. Farhi, "Exercise to Prevent Coronary Heart Diseases," American Journal of Medicine, 46: 12-27, 1969.

112. Margaria, R., P. Aghemo and E. Rovelli , "Indirect Determination of Maximum Oxygen Consumption in Man," Journal of Applied Physiology, 20: 1070-1073, 1965.

113. Maritz, J.S., J.F. Morrison, J. Peter, N.B. Strydom and C.H. Wyndom , "A Practical Method of Estimating an Individual's Maximum Oxygen Intake," Ergonomics, 4: 97-122, 1961.

114. Mayer, J. and D.W. Thomas, "Regulation of Food Intake and Obesity," Science, 156: 328-337, 1967.

115. Merriman, J.E., "Dynamic Exercise Tolerance Test: Effects in Normal Subjects of Stopping Smoking," Circulation, 36 (supp 2): 11-186, 1967.

116. Metheny, E., L. Brouha, R.E.Johnson and W.H. Forbes, "Some Physiologic Responses of Men and Women to Moderate and Strenuous Exercise: A Comparative Study," American Journal of Physiology, 137: 318-326, 1942.

117. Miller, C.E. and A.P. Remenchik, "Problems Involved in Accurately Measuring the Potassium Content of the Human Body," Annals of the New York Academy of Science, 110: 175-188, 1963.

118. Mitchell, J.H., B.J. Sproule and C.B. Chapman, "The Physiological Meaning of the Maximum Oxygen Intake Test, "Journal of Clinical Investigation, 37: 538-546, 1958.

119. Montoye, H.J., "Estimation of Habitual Physical Activity by Questionnaire and Interview," The American Journal of Clinical Nutrition, 24: 1113-1118, 1971.

120. Morris, J.N. and M.D. Crawford, "Coronary Heart Disease and Physical Activity of Work: Evidence of a National Necropsy Survey," British Medical Journal (ii), 1485-1496, 1958.

121. Morris, J.N., C. Adam, S. Chave, C. Sirey, L. Epstein and D.J. Sheehan, "Vigorous Exercise in Leisure Time and the Incidence of Coronary Heart Disease," The Lancet, 333-339, February, 1973.

122. Morris, W.H.M., "Heart Disease in Farm Workers," Canadian Medical Association Journal, 96: 821-824, 1967.

123. Morrison, D.F., Multivariate Statistical Methods, Toronto: McGraw-Hill, 1967.

124. Naughton, J. and F. Nagle, "Peak Oxygen Intake During Physical Fitness Program for Middle Aged Men," Journal of the American Medical Association, 191: 899-901, 1965.

125. Newton, J.L., "The Assessment of Maximal Oxygen Intake," The Journal of Sports Medicine and Physical Fitness, 3: 164-169, 1963.

126. Norris, A.H., T. Lundy and N.W. Shock, "Trends in Selected Indices of Body Composition in Men between the Ages of 30 and 80 years," Annals of the New York Academy of Sciences, 110: 623-639, 1963.

127. Oja, P., T. Partanen and P. Teraslinna," The Validity of three Indirect Methods of Measuring $\dot{V}O_{2\ max}$ and Physical Fitness," Journal of Sports Medicine and Physical Fitness, 10 (2): 67-71, June, 1970

128. Orban, W.A.R., editor, "Recommendations of the National Conference on Fitness and Health," Canadian Department of Health and Welfare, 1973.

129. Orlick, T.D., "A Socio-Psychological Analysis of Early Sport Participation," Unpublished Ph. D. thesis, University of Alberta, Edmonton, 1972.

130. Orpin, M.J. and P.J. Scott, "Estimation of Total Body Fat Using Skinfold Caliper Measurements," New Zealand Medical Journal, 63: 501-507, 1964.

131. Parizkova, J., "Impact of Age, Diet and Exercise on Man's Body Composition," Annals of New York Academy of Science, 110: 661-673, 1963.

132. Parizkova, J, E. Eiselt, S. Sprynarova and M. Wachthova, "Body Composition, Aerobic Capacity and Density of Muscle Capillaries in Young and Old Men," Journal of Applied Physiology, 31(3): 323-325, 1971.

133. Parker, P.A., "Acute effects of Smoking on Physical Endurance and Resting Circulation," Research Quarterly, 25: 210-217, 1954.

134. Peterson, F.J. and D.L. Kelley, "The Effect of Cigarette Smoking upon the Acquisition of Physical Fitness During Training as Measured by Aerobic Capacity," Journal of American College Health Association, 17: 250-254, 1969.

135. Pett, L.B. and G.F. Ogilvie, "The Canadian Height-Weight Survey," Human Biology, 28: 177-188, 1956.

136. Raab, W., "Physical Inactivity and the Cardiac Dynamic Cycle," Journal of Sports Medicine and Physical Fitness, 6: 38-47, 1966.

137. Rathburn, E.N. and N. Pace,"Studies on Body Composition - I. The Determination of the Total Body Fat by Means of the Body Specific Gravity," Journal of Biological Chemistry, 158: 667-676, 1945.

138. Reeves, W.E. and L.E. Morehouse, "The Acute Effect of Smoking Upon the Physical Performance of Habitual Smokers," Research Quarterly, 21: 245-248, 1950.

139. Reiff, G.G., H.J. Montoye, R.D. Remington, J.A. Napiek, H.L. Metzner and F.H. Epstein, "Assessment of Physical Activity by Questionnaire and Interview", in Physical Activity and the Heart, edited by M.J. Karvonen and A.J. Barry, Springfield, Illinois: Charles C. Thomas, 1967, Chapter 31.

140. Ribisl, P.M., "Effects of Training Upon the Maximal Oxygen Uptake of Middle Aged Men," Internationale Zeitschrift fuer Angewandte Physiologie, 27: 154-160, 1969.

141. Robinson, S., "Experimental Studies of Physical Fitness in Relation to Age," Internationale Zeitschrift fur Angewandte Physiologie, 10: 251-321, 1938.

142. Robinson, S., D.B. Dill, J.C. Ross, R.D. Robinson, J.A. Wagner and S.P. Tzankoff, "Training and Physiological Aging in Man," Federation Proceedings, 32: 1628-1634, 1973.

143. Rodahl, K., P.O. Astrand, W. Birkhead, T. Hettinger, B. Issekutz, M. Jones, and R. Weaver, "Physical Work Capacity," American Medical Association Archives of Environmental Health, 2: 499-510, 1961.

144. Rose, G.,"Smoking and Cardiovascular Disease," American Heart Journal, 85(6): 838-840, 1973.

145. Rowell, L.B., H.L. Taylor and Y. Wang,"Limitations to Prediction of Maximal Oxygen Intake," Journal of Applied Phsyiology, 19: 919-927, 1964.

146. Sabry, Z.I. (National Coordinator), Nutrition: A National Priority, A Report by Nutrition Canada to the Department of National Health and Welfare, Ottawa: Information Canada, 1973.

147. Saltin, B., "The Effect of Physical Training on the Oxygen Transporting System in Man," in Environmental Effects on Work Performance edited by G.R. Cumming, D. Snidal and A.W. Taylor, Canadian Association of Sports Sciences, 1972.

148. Saltin. B. and P. O. Astrand, "Maximal Oxygen Uptake in Athletes," Journal of Applied Physiology, 23: 353, 1967.

149. Saltin, B. and G. Grimby, "Physiological Analysis of Middle Aged and Old Former Athletes," Circulation, 38: 1104-1115, 1968.

150. Saltin, B., L.H. Hartley, A. Kilbom and I. Astrand, "Physical Training in Sedentary Middle Aged and Older Men - II", Scandinavian Journal of Clinical Laboratory Investigation, 24: 323-334, 1969.

151. Seigel,W., G. Blomquist and J.H. Mitchell, "Effects of a Quantitated Physical Training Program," Circulation, 41: 19-29, 1970.

152. Seltzer, C.C., "An Evaluation of the Effect of Smoking on Coronary Heart Disease," Journal of the American Medical Association, 203 (3): 193-200, January 15, 1968.

153. Seltzer, C.C., R.F. Goldman and J. Mayer, "The Triceps Skinfold as a Predictive Measure of Body Density and Body Fat in Obese Adolescent Girls," Pediatrics, 36: 212-218, 1965.

154. Shapiro,W. and J.L. Patterson, "Effects of Smoking and Athletic Conditioning on Ventilatory Mechanics Including Observations on the Reliability of the Forced Expirogram," American Review of Respiratory Diseases, 85: 191-199, 1962.

155. Shephard, R.J., "The Development of Cardiorespiratory Fitness," Medical Service Journal of Canada, 21: 533-544, 1965.

156. Shephard, R.J., "The Relative Merits of the Step-Test, Bicycle Ergometer and Treadmill in the Assessment of Cardiorespiratory Fitness," Internationale Zeitschrift fuer Angewandte Physiologie, 23, 219-230, 1966 (a).

157. Shephard, R.J., "World Standards of Cardiorespiratory Performance," Archives of Environmental Health, 13: 664-672, 1966 (b).

158. Shephard, R.J.,"Normal Levels of Activity in Canadian City Dwellers," Canadian Medical Association Journal, 97: 313-318, 1967.

159. Shephard, R.J., "The Prediction of $\dot{V}O_{2\ max}$ from Post Exercise Pulse Readings," Internationale Zeitschrift fuer Angewandte Physiologie, 24: 31-38, 1967.

160. Shephard, R.J., Endurance Fitness, Toronto: University of Toronto Press, 1969.

161. Shephard, R.J., "For Exercise Testing Please: A Review of Procedures Available to the Clinician," Extrait du Bulletin de Physio-Pathologie Respirtoire, 6: 425-474, 1970.

162. Shephard, R.J., "Computer Programs for Solutions of the Astrand Nomogram and the Calculation of Body Surface Area," Journal of Sports Medicine and Physical Fitness, 10: 206-210, 1970.

163. Shephard, R.J., C. Allen, A.J.S. Benade, C.T.M. Davies, P.E. DiPamero, R. Hedman, J.E. Merriman, K. Myhre and R. Simmons, "Standardization of Submaximal Exercise Tests," Bulletin: World Health Organization, 38: 765-776, 1968(b).

164. Shephard, R.J., C.Allen, A.J.S. Benade, C.T.M. Davies, P.E. diPampero, R. Hedman, J.E. Merriman, K. Myhre, and R.Simmons, "The Maximum Oxygen Intake; An International Reference Standard of Cardiorespiratory Fitness," Bulletin: World Health Organization, 38: 757-764, 1968 (a).

165. Shephard, R.J., G. Jones, K. Ishii, M. Kaneko, and A.J. Olbrecht, "Factors Affecting Body Density and Thickness of Subcutaneous Fat," The American Journal of Clinical Nutrition, 22: 1175-1189, 1969.

166. Siri, W.E., "The Gross Composition of the Body," in Advances in Biological and Medical Physiology, edited by J.H. Lawrence and C.A. Tobias, London and New York: Academic Press., 1956.

167. Skinner, J.S., J.O. Halloszy and T.K. Cureton, "Effects of a Program of Endurance Exercises on Physical Work Capacity," American Journal of Cardiology, 14: 747-752, 1964.

168. Sloan, A.W. and J.B.Weir, "Nomogram for Prediction of Body Density and total Body Fat from Skinfold Measurement," Journal of Applied Physiology, 28:221-222, 1970.

169. Spain, D.M. and V.A. Bradess, "Occupational Physical Activity and the Degree of Coronary Atherosclerosis in 'normal' men," Circulation, 22: 239-242, 1960.

170. Steinkamp, R.C., N.L. Cohen, W.R.Gaffery, T. McKay, B. Bron, G. Bron, W.E. Siri and E. Isaacs, "Measures of Body Fat and Related Factors in Normal Adults - II", Journal of Chronic Disease, 18: 1291-1307, 1965.

171. Stouffer, J.R., "Relationship of Ultrasonic Measurements and X-rays to Body Composition," Annals of New York Academy of Science, 110: 31-39, 1963.

172. Tanner, J.M. and R.H. Whitehouse, "The Harpenden Skinfold Caliper," American Journal of Physical Anthropology, 13: 743-746, 1955.

173. Tatsuoka, M.M., Selected Topics in Advanced Statistics: An Elementary Approach, No. 4 Significance Tests, Champaign, Illinois: Institute for Personality andAbility Testing, 1971.

174. Tatsuoka, M. M. , Selected Topics in Advanced Statistics: An Elementary Approach, No. 6 Discriminant Analysis, Champaign, Illinois: Institute for Personality and Ability Testing, 1971.

175. Tatsuoka, M. M., Multivariate Analysis; Techniques for Educational and Psychological Research, New York: Wiley, 1971.

176. Taylor, H.L., "Occupational Factors in the Study of Coronary Heart Disease and Physical Activity," Canadian Medical Association Journal, 96: 825-831, 1967.

177. Taylor, H.L., E. Buskirk and A. Henschel, "Maximum Oxygen Intake as an Objective Measure of Cardiorespiratory Performance," Journal of Applied Physiology, 8: 73-80, 1955.

178. Taylor, H.L., Y Wang, L. Rowell and G. Blomquist, "The Standardization and Interpretation of Submaximal and Maximal Tests of Physical Work Capacity," Pediatrics: Supplementum, 32: 703-722, 1963.

179. Taylor, H.L., E.R. Buskirk and R.D. Remington, "Controlled Trials of the Prevention of Coronary Heart Disease," Federation Proceedings, 32: 1623-1627, 1973.

180. Teraslinna, P., A.H. Ismail and D.F. MacLeod, "Nomogram by Astrand and Ryhming as a Prediction of $VO_{2\,max}$," Journal of Applied Physiology, 21: 513-515, 1966.

181. Truett, J., J. Cornfield and W. Kannel, "A Multivariate Analysis of the Risk of Coronary Heart Disease in Framingham," Journal of Chronic Disease, 20: 511-524, 1967.

182. Von Dobeln, W., "Human Standard and Maximal Metabolic Rate in Relation to Fat Free Body Mass," Acta Physiologica Scandinavica, Supp 126: 1-79, 1956.

183. Von Dobeln, W., I. Astrand and A. Bergstrom, "An Analysis of Age and Other Factors Related to Maximal Oxygen Uptake," Journal of Applied Physiology, 22: 934-938, 1967.

184. Wessel, J.A., A. Ufer, W.P. Van Huss, and D. Cedarquist, "Age trends of Various Components of Body Composition and Functional Characteristics in Women aged 20 to 69 Years," Annals of the New York Academy of Sciences, 110: 608-622, 1963.

185. Wessel, J.A., H.J. Montoye and H. Mitchell, "Physical Activity Assessment: by Recall Record," The American Journal of Public Health, 55: 1430-1436, 1965.

186. Wilhelmsen, L., H. Wedel and G. Tibblin, "Multivariate Analysis of Risk Factors for Coronary Heart Disease," Circulation, 48: 950-958, 1973 (Nov.)

187. Wilmore, J.H., J. Royce, R.N. Girandola, F.I. Katch, and V.L. Katch, "Body Composition Changes with a 10 Week Program of Jogging," Medicine and Science in Sports, 2: 113-117, 1970.

188. Wilmore, J.H. and W.L. Haskell, "Use of the Heart Rate- Energy expenditure Relationship in the Individualized Prescription of Exercise," American Journal of Clinical Nutrition, 24: 1186-1192, 1971.

189. Winer, B.J., Statistical Principles in Experimental Design, 2nd Edition, Toronto: McGraw-Hill, 1971.

190. Wyndom, C.H., "Submaximal Tests for Estimation of Maximum Oxygen Intake," Canadian Medical Association Journal, 96: 736-742, 1967.

191. Wyndom, C.H., N.B. Strydom, J.S. Maritz, J.F. Morrison, J. Peter and Z.V.Potgieter, "Maximum Oxygen Intake and Maximum Heart Rate During Strenuous Work," Journal of Applied Physiology, 14: 927-936, 1959.

192. Young, C.M.,"Body Composition and Body Weight - Criteria of Overnutrition," Canadian Medical Association Journal, 93: 900-910, 1965.

193. Young, C.M., J. Blondin, R. Tensuan and J.H. Foyer, "Body Composition Studies of 'Older' Women, Thirty to Seventy Years of Age," Annals of New York Academy of Sciences, 110: 589-607, 1963.

194. Zwi, S., H.I. Goldman, A. Levin, "Cigarette Smoking and Pulmonary Function in Healthy Young Adults," American Revolution of Respiratory Diseases, 89: 73-81, 1964.

APPENDICES

APPENDIX A

INITIAL SCREENING QUESTIONNAIRE

INITIAL SCREENING QUESTIONNAIRE

NAME ______________________________ AGE _____ SEX ______ SUBJECT # ___

ADDRESS ____ TELEPHONE # _______

	YES	NO
1. Have you ever had heart trouble? e.g. coronary, angina, heart failure, infarct, murmur, heart attack.	☐	☐
2. Do you suffer or have you ever suffered from discomfort or pain in the chest?	☐	☐
3. Do you have or have you ever had high blood pressure?	☐	☐
4. Have you ever fainted when exercising or working hard?	☐	☐
5. Are you on any medications? If so, please list them if possible (birth control pills not included).	☐	☐
6. Have you been in hospital in the past 6 months? If so, please list the reason.	☐	☐

RECALL

1. Since your last exercise test, have you had any illness requiring medical attention? If so, please give the nature of your illness.	☐	☐
2. Have you had any pain or discomfort in the chest since your last test?	☐	☐

APPENDIX B

FITNESS AND ACTIVITY APPRAISAL

FITNESS AND ACTIVITY APPRAISAL

NOTE: This information will be kept confidential.

Name ______________________, Age____, Sex_____, Subject No. ____

1. Which of the following most accurately describes your activity over the last 3 months?

Check one:

_______(A) No deliberate activity to improve my physical fitness.

_______(B) Occasional moderate activity (walking, jogging, cycling, tennis, recreational sports, swimming, etc.) but not on a regular basis.

_______(C) Regular moderate activity (same as above), but averaging 2-3 sessions per week.

_______(D) Very Frequent regular activity (same as above), but averaging 4-5 sessions per week.

_______(E) Training regularily for a specific sport (3-5 workouts per week that produce a heavy sweat).

2. How do you rate YOUR fitness relative to the other people of you age on your street (or in your classroom)?

______(A) Below Average, _____(B) Average,

______(C) Above Average

3. Which of the following best describe your current smoking habits?

______(A) I have never smoked.

______(B) I have given up smoking.

______(C) I smoke cigarettes.

______(D) I smoke a pipe or cigars.

4. My current consumption of cigarettes per day:

____(A) None, ____(B) 1-10, ___(C) 11-25,

____(D) More than 25

5. Briefly describe your physical activity for only yesterday.

(Eg - walked to work or school and number of blocks, played golf, volleyball, exercised at home for number of minutes, cycled, danced, etc.)

____

____

____

____

____

Note: Answer the following two questions only if you are over 25 years old.

6. How do you rate your fitness relative to what it was 10 years ago?

_____(A) Improved, ____(B) The Same, ___(C) Worse

_____(D) Much Worse

7. How is your weight relative to 10 years ago?

______(A) Gain of over 20 pounds

______(B) Gain of 5-20 pounds

______(C) About the same to within 5 pounds

______(D) Loss of 5-20 pounds

______(E) Loss of more than 20 pounds

_____ Please check here if you would like a confidential copy of your test results.

Home Address: ______________________

Telephone Number: ____________

APPENDIX C

ANTHRO - STRENGTH DATA SHEET

ANTHRO - STRENGTH DATA SHEET

SUBJECT	HEIGHT	WEIGHT	TRICEPS FAT	GRIP STRENGTH

APPENDIX D

TEST ADMINISTRATOR DATA SHEET

TEST ADMINISTRATOR DATA SHEET

Subject Number	Station	Quit Reason	Workload	Manual H. R.	Workload	Manual H. R.	Workload	Manual H. R.

APPENDIX E

QUIT CODE

QUIT CODE

A - Stopped prior to exercise - ECG abnormality

B - Stopped prior to exercise - other reason

C - Stopped during exercise - ST-T changes

M - Stopped during exercise - frequent or multifocal pvc's

T - Stopped during exercise - ventricular tachycardia

S - Stopped during exercise - frequent svpc's

H - Stopped during exercise - development of block

E - Stopped during exercise - other ECG abnormality

P - Stopped during exercise - pulse over limit

F - Stopped during exercise - fatigue

D - Stopped during exercise - dyspnoea

L - Stopped during exercise - legs

I - Stopped during exercise - chest pain

X - Unable to complete test - other reason, eg. coordination

APPENDIX F

DATA CODING FORM

STAT = Test Station
QUIT = Reason for stopping
SEX = M,F
AGE = In years

AGE
1 = 10 - 19
2 = 20 - 29
3 = 30 - 39
4 = 40 - 49
5 = 50 - 59
6 = 60 - 65
7 = 70 - 79

TST
1 = Bike
2 = Step
3 = 10% Pulse
4 = 10% Rhythm

GP
1 = Public School
2 = High School
3 =
4 =

LOCATION ____________________
DATE ____________________ (MORN/AFTER/EVEN)
PERSONNEL: ____________________
SUPER ____________________
M.D. ____________________
NURSE ____________________
RECORDER ____________________

1 4	6	7		10	11	12	13	14 17	18 21	22 24	25 26	34		40		43			54	60	62 64	66 69	72 80
Subject Number	[illegible]	[illegible]	[illegible]	Age	[illegible]	[illegible]	GP	Height	Weight	Fat	Stren	HR 1	HR 2	HR 3	HR 4	HR 5	HR 6	HR 7	HR 8	HR 9	Working HR	Work Load	

APPENDIX G

TEST INFORMATION FOR SUBJECTS

TEST INFORMATION FOR SUBJECTS

CLOTHING AND FOOTWEAR:

The two test may be taken in normal clothing for men. Preferably, the women should wear slacks with a short sleeve, buttoned front, cotton blouse. High platformed shoes will be troublesome in doing the tests, but the tests may be done in stocking feet or bare feet. Athletic equipment or clothing is not necessary.

TAKING YOUR OWN PULSE:

During the step test you will be asked to count your pulse rate for a ten second period at a specified time. Complete instructions will be given to you prior to starting the test. However, we would appreciate it if you practiced taking your pulse prior to being tested. We would like the pulse taken at the wrist on the underhand side of the arm on the thumb side. The pulse should be taken with the first two fingers of the opposite hand. Do not use your thumb to take the pulse count.

EATING AND SMOKING:

If at all possible, we would like you to refrain from smoking or eating two hours prior to your scheduled test time. A rule of thumb that you should follow is to maintain the same routine prior to both test session.

APPENDIX H

STATISTICAL ANALYSIS OF DATA

SUMMARY TABLES

TABLE H-I

Two Way Analysis of Variance of Aerobic Capacity Data For Male High, Low Capacity Groupings For Six Age Categories

Source of Variation	Sum of Squares	D.F.	Mean Squares	F Ratio
A. (capacity)	12133.90	1	12133.90	730.26**
B. (age)	11902.60	5	2380.51	143.27**
AB (age x capacity)	441.38	5	88.28	5.31**
Error	5134.31	309	16.62	

** denotes significance at $p < 0.01$

TABLE H-II

Scheffé Contrasts for High versus Low Aerobic Capacity Groups for Male Subjects

Age Group	Contrast	$\Sigma c^2/n$	F Ratio
14 - 19	17.13	0.080	220.80**
20 - 29	16.84	0.066	258.51**
30 - 39	14.31	0.041	300.99**
40 - 49	12.70	0.077	126.09**
50 - 59	10.37	0.103	63.19**
60 - 74	10.90	0.190	37.64**

** denotes significance at $p < 0.01$

TABLE H-III

Two Way Analysis of Variance of Aerobic Capacity Data For Female High, Low Capacity Grouping For Six Age Categories

Source of Variation	Sum of Squares	D.F.	Mean Squares	F Ratio
A (capacity)	17867.70	1	17867.70	1307.32**
B (age)	8986.75	5	1797.35	131.51**
AB (age x capacity)	1298.12	5	259.63	19.00**
Error	5234.62	383	13.67	

** denotes significance at $p < 0.01$

TABLE H-IV

Scheffé Contrasts for High versus Low Aerobic Capacity Groups for Female Subjects

Age Group	Contrast	$\Sigma c^2/n$	F Ratio
14 - 19	21.81	0.054	644.55**
20 - 29	17.26	0.048	454.05**
30 - 39	14.32	0.042	357.44**
40 - 49	12.92	0.071	171.80**
50 - 59	11.81	0.075	136.02**
60 - 74	9.62	0.118	57.39**

** denotes significance at $p < 0.01$

TABLE H-V

Summary of Hotellings' T^2 Test Results for Male Data

Age Group	HOTELLINGS' T^2 TEST				MULTIPLE COMPARISONS					
					Activity Level		Smoking Habits		Fatness	
	T^2	df_1	df_2	F Ratio	T^2	F Ratio	T^2	F Ratio	T^2	F Ratio
14 - 19	17.82	3	46	5.694**	13.74	4.390**	1.61	0.514	8.30	2.651
20 - 29	24.23	3	57	7.802**	9.85	3.173*	10.32	3.334*	8.86	2.854*
30 - 39	30.83	3	94	10.064**	15.29	4.992**	0.00	0.000	18.80	6.136**
40 - 49	11.09	3	48	3.548*	3.08	0.986	0.47	0.150	10.46	3.347*
50 - 59	4.04	3	35	1.274	0.11	0.036	2.88	0.909	2.00	0.632
60 - 74	4.97	3	17	1.482	2.87	0.857	0.49	0.147	3.07	0.917

** denotes significance at $p < 0.01$
* denotes significance at $p < 0.05$

TABLE H-VI

Summary of Hotellings' T^2 Test Results for Female Data

Age Group	HOTELLINGS' T^2 TEST				MULTIPLE COMPARISONS Activity Level		Smoking Habits		Fatness	
	T^2	df_1	df_2	F Ratio	T^2	F Ratio	T^2	F Ratio	T^2	F Ratio
14 - 19	25.93	3	70	8.418**	18.78	6.088**	0.85	0.274	10.43	3.380*
20 - 29	6.32	3	79	2.055	3.89	1.264	0.87	0.284	2.64	0.857
30 - 39	19.73	3	91	6.436**	8.12	2.650	0.41	0.135	11.33	3.696*
40 - 49	11.69	3	52	3.754*	5.35	1.717	0.02	0.006	5.44	1.746
50 - 59	8.52	3	49	2.729	0.80	0.255	0.25	0.015	7.11	2.176
60 - 74	0.68	3	30	0.212	0.04	0.012	0.62	0.195	0.06	0.097

** denotes significance at $p < 0.01$
* denotes significance at $p < 0.05$

TABLE H-VII

Summary of Linear Discriminant Function Weights and Calaculated F's for Male Subjects

	LINEAR DISCRIMINANT FUNCTION WEIGHTS					
Age Group	Activity Level	Smoking Habits	Fatness	df_1	df_2	F Ratio
14 - 19	0.55464	-0.03489	0.83203	3	46	5.694**
20 - 29	0.35515	0.55942	0.74894	3	57	7.802**
30 - 39	0.53750	-0.16764	0.82643	3	94	10.064**
40 - 49	0.17431	0.12317	0.97696	3	48	3.548*
50 - 59	-0.04855	0.77872	-0.62548	3	35	1.274
60 - 74	0.40381	0.07050	0.91212	3	17	1.483

** denotes significance at $p < 0.01$
* denotes significance at $p < 0.05$

TABLE H-VIII

Summary of Linear Discriminant Function Weights and Calculated F's for Female Subjects

	LINEAR DISCRIMINANT FUNCTION WEIGHTS					
Age Group	Activity Level	Smoking Habits	Fatness	df_1	df_2	F Ratio
14 - 19	0.78914	0.21389	0.57576	3	70	8.416**
20 - 29	0.71939	-0.40500	0.56432	3	79	2.055
30 - 39	0.60964	-0.23873	0.75588	3	91	6.436**
40 - 49	0.67972	-0.14320	0.71936	3	52	3.753*
50 - 59	-0.44577	0.17881	0.87711	3	49	2.729
60 - 74	-0.17652	0.97563	0.13032	3	30	0.212

** denotes significance at $p < 0.01$
* denotes significance at $p < 0.05$

TABLE H-IX

Summary of Two Way MANOVA Including Multiple Comparisons for Male Data

Source of Variation	df_1	df_2	F Ratio
"A" Effect Vector (capacity)	3	307	16.157**
$A_1 - A_2$			
Variable 1 (activity)	3	307	8.356**
Variable 2 (smoking)	3	307	.767
Variable 3 (fatness)	3	307	10.096**
"B" Effect Vector (age)	15	847.9	4.668**
$B_1 - B_2$			
Var 1	15	847.9	1.342
Var 2	15	847.9	.494
Var 3	15	847.9	.314
$B_1 - B_3$			
Var 1	15	847.9	1.369
Var 2	15	847.9	.528
Var 3	15	847.9	1.291
$B_1 - B_4$			
Var 1	15	847.9	2.125**
Var 2	15	847.9	.125
Var 3	15	847.9	.829
$B_1 - B_5$			
Var 1	15	847.9	1.282
Var 2	15	847.9	0.044
Var 3	15	847.9	0.385
$B_1 - B_6$			
Var 1	15	847.9	1.544
Var 2	15	847.9	0.144
Var 3	15	847.9	0.050

TABLE H-IX (continued)

Source of Variation	df_1	df_2	F Ratio
$B_2 - B_3$			
Var 1	15	847.9	0.012
Var 2	15	847.9	0.002
Var 3	15	847.9	0.050
$B_2 - B_4$			
Var 1	15	847.9	0.137
Var 2	15	847.9	0.117
Var 3	15	847.9	0.154
$B_2 - B_5$			
Var 1	15	847.9	0.010
Var 2	15	847.9	0.192
Var 3	15	847.9	0.016
$B_2 - B_6$			
Var 1	15	847.9	0.166
Var 2	15	847.9	0.020
Var 3	15	847.9	0.037
$B_3 - B_4$			
Var 1	15	847.9	0.263
Var 2	15	847.9	0.109
Var 3	15	847.9	0.011
$B_3 - B_5$			
Var 1	15	847.9	0.042
Var 2	15	847.9	0.187
Var 3	15	847.9	0.123
$B_3 - B_6$			
Var 1	15	847.9	0.255
Var 2	15	847.9	0.014
Var 3	15	847.9	0.342
$B_4 - B_5$			
Var 1	15	847.9	0.054
Var 2	15	847.9	0.014
Var 3	15	847.9	0.053

TABLE H-IX (continued)

Source of Variation	df_1	df_2	F Ratio
$B_4 - B_6$			
Var 1	15	847.9	0.017
Var 2	15	847.9	0.012
Var 3	15	847.9	0.226
$B_5 - B_6$			
Var 1	15	847.9	0.094
Var 2	15	847.9	0.040
Var 3	15	847.9	0.076
AB Interaction Vector (age x capacity)	15	847.9	1.445

** denotes significance at $p < 0.01$
* denotes significance at $p < 0.05$

TABLE H-X

Summary of Two Way MANOVA Including Multiple Comparisons for Female Data

Source of Variation	df_1	df_2	F Ratio
"A" Effect Vector (capacity)	3	381	12.617**
$A_1 - A_2$			
Var 1	3	381	5.378**
Var 2	3	381	0.143
Var 3	3	381	7.895**
"B" Effect Vector (age)	15	1052.2	2.406**
$B_1 - B_2$			
Var 1	15	1052.2	0.474
Var 2	15	1052.2	0.137
Var 3	15	1052.2	0.065
$B_1 - B_3$			
Var 1	15	1052.2	0.252
Var 2	15	1052.2	0.0002
Var 3	15	1052.2	0.051
$B_1 - B_4$			
Var 1	15	1052.2	0.039
Var 2	15	1052.2	0.006
Var 3	15	1052.2	0.387
$B_1 - B_5$			
Var 1	15	1052.2	0.398
Var 2	15	1052.2	0.001
Var 3	15	1052.2	0.503
$B_1 - B_6$			
Var 1	15	1052.2	0.088
Var 2	15	1052.2	0.003
Var 3	15	1052.2	0.337
$B_2 - B_3$			
Var 1	15	1052.2	0.047
Var 2	15	1052.2	0.146
Var 3	15	1052.2	0.254

TABLE H-X

Source of Variation	df_1	df_2	F Ratio
$B_2 - B_4$			
Var 1	15	1052.2	0.192
Var 2	15	1052.2	0.178
Var 3	15	1052.2	0.759
$B_2 - B_5$			
Var 1	15	1052.2	0.0004
Var 2	15	1052.2	0.135
Var 3	15	1052.2	0.913
$B_2 - B_6$			
Var 1	15	1052.2	0.057
Var 2	15	1052.2	0.119
Var 3	15	1052.2	0.623
$B_3 - B_4$			
Var 1	15	1052.2	0.066
Var 2	15	1052.2	0.009
Var 3	15	1052.2	0.201
$B_3 - B_5$			
Var 1	15	1052.2	0.044
Var 2	15	1052.2	0.002
Var 3	15	1052.2	0.294
$B_3 - B_6$			
Var 1	15	1052.2	0.007
Var 2	15	1052.2	0.004
Var 3	15	1052.2	0.184
$B_4 - B_5$			
Var 1	15	1052.2	0.170
Var 2	15	1052.2	0.002
Var 3	15	1052.2	0.008
$B_4 - B_6$			
Var 1	15	1052.2	0.015
Var 2	15	1052.2	0.0001
Var 3	15	1052.2	0.002

TABLE H-X

Source of Variation	df_1	df_2	F Ratio
$B_5 - B_6$			
Var 1	15	1052.2	0.056
Var 2	15	1052.2	0.001
Var 3	15	1052.2	0.001
AB Interaction Vector (age x capacity)	15	1052.2	1.532

** denotes significance at $p < 0.01$

TABLE H-XI

Summary of Results of Two Way ANOVA for High Aerobic Capacity Male and Female Groups

Source of Variation	Sum of Squares	D.F.	Mean Squares	F Ratio
A (male-female)	1707.31	1	1707.31	89.79**
B (age)	15468.30	5	3093.66	162.70**
AB (age x sex)	234.38	5	46.88	2.47*
Error	6312.88	332	19.01	

** denotes significance at $p < 0.01$
* denotes significance at $p < 0.05$

TABLE H-XII

Scheffé Contrasts for Male versus Female High Aerobic Capacity Groups

Age Group	Contrast	$\Sigma c^2/n$	F Ratio
14 - 19	16.72	0.070	209.72**
20 - 29	6.95	0.059	43.00**
30 - 39	4.45	0.042	24.74**
40 - 49	2.66	0.077	4.84*
50 - 59	2.90	0.085	5.20*
60 - 74	5.70	0.160	10.68**

** denotes significance at $p < 0.01$
* denotes significance at $p < 0.05$

TABLE H-XIII

Summary of Results of Two Way ANOVA for Low Aerobic Capacity Male and Female Groups

Source of Variation	Sum of Squares	D.F.	Mean Squares	F Ratio
A (male-female)	2198.87	1	2198.87	213.25**
B (age)	5789.63	5	1157.92	112.30**
AB (age x sex)	718.81	5	143.76	13.94**
Error	3712.06	360	10.31	

** denotes significance at $p < 0.01$

TABLE H-XIV

Scheffé Contrasts for Male Versus Female Low Aerobic Capacity Groups

Age Group	Contrast	$\Sigma c^2/n$	F Ratio
14 - 19	11.40	0.060	209.81**
20 - 29	5.37	0.053	52.78**
30 - 39	4.47	0.041	47.46**
40 - 49	8.29	0.071	11.26**
50 - 59	4.33	0.089	20.50**
60 - 74	3.47	0.133	8.78**

** denotes significance at $p < 0.01$

TABLE H-XV

Summary of Hotellings' T^2 Test Results for Male-Female High and Low Capacity Group Data

Age Group	Capacity Group	HOTELLINGS' T^2 TEST				MULTIPLE COMPARISONS					
						Activity Level		Smoking Habits		Fatness	
		T^2	df_1	df_2	F Ratio	T^2	F Ratio	T^2	F Ratio	T^2	F Ratio
14-19	High	58.55	3	53	18.807**	8.64	2.775	1.21	0.390	54.93	17.645**
	Low	43.28	3	63	13.984**	8.79	2.840*	0.38	0.122	39.45	12.740**
20-29	High	47.31	3	64	15.293**	3.54	1.144	2.87	0.928	40.86	13.206**
	Low	25.89	3	72	8.397**	0.09	0.029	6.56	2.128	17.74	5.752**
30-39	High	48.55	3	91	15.835**	2.38	0.776	1.05	0.342	44.60	14.546**
	Low	23.38	3	94	7.630**	0.36	0.117	2.909	0.950	21.36	6.972**
40-49	High	44.34	3	48	14.189**	1.26	0.402	0.03	0.009	38.93	12.458**
	Low	27.98	3	52	8.980**	0.83	0.266	0.56	0.179	26.05	8.363**
50-59	High	23.46	3	43	7.471**	1.85	0.590	0.53	0.170	21.94	6.989**
	Low	45.40	3	41	14.430**	0.04	0.012	0.77	0.243	42.81	13.605**
60-74	High	35.55	3	21	10.819**	0.08	0.023	0.03	0.009	32.50	9.890**
	Low	40.11	3	26	12.414**	2.23	0.690	1.97	0.611	27.13	8.396**

** denotes significance at $p < 0.01$

* denotes significance at $p < 0.05$

TABLE H-XVI

Summary of Linear Discriminant Function Weights and Calculated F Ratios for Male and Female Subjects

Age Group	Capacity Group	LINEAR DISCRIMINANT FUNCTION WEIGHTS			df_1	df_2	F Ratio
		Activity Level	Smoking Habits	Fatness			
14-19	High	0.09138	0.15787	0.98322	3	53	18.806**
	Low	0.29936	-0.01981	0.95394	3	63	13.984**
20-29	High	-0.02865	0.29206	0.95597	3	64	15.293**
	Low	0.20598	-0.56028	0.80228	3	72	8.397**
30-39	High	0.15135	-0.17946	0.97205	3	91	15.834**
	Low	-0.00029	-0.36734	0.93009	3	94	7.630**
40-49	High	-0.21441	0.17858	0.96028	3	48	14.189**
	Low	-0.23403	-0.13279	0.96312	3	52	8.980**
50-59	High	0.22155	0.08098	0.97178	3	43	7.471**
	Low	-0.10782	0.25861	0.95994	3	41	14.429**
60-74	High	-0.21422	0.10215	0.97143	3	21	10.819**
	Low	-0.11383	-0.48074	0.86944	33	26	12.414**

** denotes significance at $p < 0.01$

APPENDIX I

RAW DATA

KEY TO RAW DATA TABLES

COLUMNS	
1	Aerobic Capacity Group
2	Age Group
3 - 6	Subject Number
7	Sex: Male = 1, Female = 2
8 - 9	Age: actual chronological age
10	Age Group
11	Test Site
12	Raw Physical Activity Score (1 - 5)
13	Raw Smoking Score (1 - 4)
14	High (1) or Low (3) Aerobic Capacity Group
15 - 18	Recoded Physical Activity Score: 10.0, 20.0, or 30.0
19 - 22	Recoded Smoking Habit Scores: 10.0 or 20.0
23 - 26	Raw Triceps Skinfold Measures, mm.

TABLE I-I

Male Subjects 14 - 19 Years

```
1110691141131120.010.0 7.3
1110081161131120.010.0 4.6
1110401151141110.010.0 6.2
1110071151133120.020.0 7.0
1110581151142110.010.0 7.8
1110871141151110.010.0 6.1
1110571151151110.010.0 5.4
1110101151141110.010.0 7.1
1110141161141110.010.0 9.6
1110501151121130.010.0 9.0
1110261161141110.010.0 9.0
1110211151131120.010.0 6.2
1110701141151110.010.0 6.4
1110781151131120.010.0 7.0
1110181151142110.010.0 7.8
1110361161151110.010.0 6.8
1110621181123130.020.0 4.2
1110741151131120.010.0 5.1
1110611151153110.020.0 7.2
1110551151141110.010.0 7.0
1110821141131120.010.0 5.2
1110921141131120.010.010.9
1110051151131120.010.0 8.1
1110171151141110.010.0 6.4
2110151161123330.020.0 8.6
2110751141123330.020.0 6.6
2110841151131320.010.0 8.1
2110641151141310.010.0 7.8
2110651161131320.010.0 5.5
2110481151141310.010.0 6.8
2110021161123330.020.016.4
2110061151131320.010.0 5.0
2110711141131320.010.0 5.6
2112151151151310.010.0 5.6
2110281161123330.020.018.2
2110301171131320.010.016.2
2110331171133320.020.0 9.2
2110231171121330.010.0 6.8
2110761161121330.010.012.8
2110911171142310.010.0 7.4
2110031161121330.010.012.8
2110241151123330.020.010.2
2110351151121330.010.0 6.5
2110511151131320.010.0 7.0
2110521161132320.010.0 6.4
2110321151133320.020.0 7.6
2110721141121330.010.014.6
2110801141131320.010.011.2
2112141161122330.010.0 7.8
2110411161131320.010.014.1
```

TABLE I-II

Male Subjects 20 - 29 Years

```
12 4461232021130.010.0 9.7
1218471242651110.010.0 4.4
12 3371212031120.010.0 7.2
1213251262231120.010.0 9.5
1214241272521130.010.010.8
12 1271242021130.010.018.0
1214231222541110.010.0 8.3
12 2231262032120.010.013.4
1214381272541110.010.0 4.8
1212381292451110.010.011.6
1214361222531120.010.0 5.8
12 2071242633120.020.0 8.2
12  971292032120.010.0 4.0
12 4431262023130.020.0 6.6
1215591212521130.010.0 9.2
1215601262521130.010.011.8
12 3411232033120.020.0 5.5
1212401292431120.010.0 6.0
1214291252541110.010.0 8.3
1214181292521130.010.0 9.6
1213291212422130.010.0 6.9
1215991292642110.010.0 9.9
1215961232033120.020.0 9.2
1216021202524130.020.0 7.8
12 1031282021130.010.0 5.6
12 1051202031120.010.0 8.2
1213301212014130.020.0 8.6
1213361212413130.020.0 7.4
2212411292432320.010.0 9.0
2213271282251310.010.0 9.8
2214421242521330.010.0 6.6
2214191282523330.020.0 8.2
22 2081262234320.020.012.8
22 4381272021330.010.0 5.6
22 4391262033320.020.011.2
22 6991282021330.010.016.7
22 4451282224330.020.011.4
22 1071212023330.020.011.4
22  981222023330.020.0 5.2
2213311232423330.020.020.6
2216041272621330.010.0 6.3
2216011252623330.020.016.2
2212391212413330.020.0 5.5
22 4371212021330.010.019.0
22 2051262633320.020.011.4
22 1041272013330.020.013.2
2214201272523330.020.015.2
2214151222723330.020.010.2
2214251262523330.020.014.6
2215621282521330.010.0 8.2
```

TABLE I-II (continued)

```
2215581272522330.010.011.2
2214261262523330.020.020.3
2214341292524330.020.011.6
22 5061272023330.020.0 6.6
2213341242423330.020.0 7.2
2214041262721330.010.010.2
2216031242021330.010.0 9.4
2216001282024330.020.0 7.5
2214411262541310.010.017.1
2214391282524330.020.0 8.5
22 3401272023330.020.017.0
```

TABLE I-III

Male Subjects 30 - 39 Years

```
1312601303452110.010.010.6
1312571313423130.020.0 7.5
1315701323524130.020.0 8.9
1314701333533120.020.0 7.0
1314551353513130.020.011.0
13 1391313042110.010.0 8.0
1312631353254110.020.0 9.8
1312511353421130.010.0 6.4
1312531383422130.010.0 5.4
1314711363521130.010.014.0
1312551333412130.010.014.0
1313231333042110.010.0 7.6
1312441303432120.010.0 9.6
13 1141383042110.010.0 7.4
1314721333533120.020.015.1
1315641373024130.020.017.0
1312671373423130.020.0 8.3
13 5031303631120.010.0 9.2
13 5531313024130.020.0 6.2
1314531313523130.020.0 5.0
1314451383521130.010.010.8
1314631343541110.010.011.0
1318451373041110.010.0 8.3
13  111303223130.020.0 6.8
1314511303532120.010.0 9.8
1314311323523130.020.0 9.9
1314491303533120.020.0 4.8
1312431313421130.010.0 6.2
1312651323221130.010.016.0
1313241323432120.010.0 7.4
13   31313231120.010.017.0
13 4271353032120.010.0 4.4
1315381393523130.020.0 8.5
13 2321363043110.020.011.2
13 2361323033120.020.0 7.6
1313951343432120.010.0 8.4
13   61343233120.020.021.0
1314541303523130.020.0 6.9
13  101353231120.010.012.8
13   21313224130.020.017.4
1313211363442110.010.0 4.6
13 5641343042110.010.010.6
13 5681323041110.010.0 5.4
13 5261363634120.020.0 8.0
13 4291303041110.010.0 6.6
13 4321343013130.020.0 4.8
13 3351333031120.010.0 6.8
13 2351343021130.010.0 6.6
13 5251323652110.010.0 5.9
```

TABLE I-III (continued)

```
23   51303223330.020.026.0
2315711323022330.010.012.6
2314601373522330.010.012.4
2315691333522330.010.018.1
2314571323524330.020.0 9.7
23   11363231320.010.019.4
23 4231353021330.010.014.6
23 4251333023330.020.011.6
23 4341393013330.020.0 9.0
23 1411353022330.010.012.8
23 2371303024330.020.010.4
23 3311313032320.010.0 7.8
2314621323524330.020.016.3
2315681323521330.010.024.4
23 5701343613330.020.019.8
23 1341353022330.010.0 5.8
23 4311323023330.020.019.0
23 4221353042310.010.011.4
23 5671353012330.010.010.0
2312451383421330.010.013.7
23 5661333012330.010.018.4
2313971313732320.010.0 9.6
23 1151343011330.010.015.8
2315731393012330.010.014.2
2315721343521330.010.018.5
2314591363533320.020.010.8
2314471323524330.020.015.0
2313171333233320.020.021.5
2312691363424330.020.015.3
2312611323431320.010.012.2
23  161353322330.010.025.2
23 5551393022330.010.0 8.2
23 3341303031320.010.0 7.5
2314611343523330.020.014.4
23 4331323621330.010.0 8.6
2313981363713330.020.0 8.2
23  151383312330.010.025.4
23  141343332320.010.022.4
2314481343521330.010.018.6
23 6941383023330.020.0 8.6
2312711313223330.020.011.2
2312641323223330.020.0 9.8
2314691313532320.010.011.0
23 1401353022330.010.0 6.8
23 1181353023330.020.0 5.8
23 4401333233320.020.0 6.6
2314521353513330.020.012.5
2314011323744310.020.0 6.0
23 7011343021330.010.0 7.2
```

TABLE I-IV

Male Subjects 40 - 49 Years

```
14  271404222130.010.0 7.0
14 2121494013130.020.011.2
14 4001404023130.020.0 8.0
1412901494413130.020.0 9.6
1413011444421130.010.012.0
1415271424521130.010.0 7.6
1413001454422130.010.0 4.2
14 4011434032120.010.0 5.8
1413851434241110.010.0 7.4
1419031444652110.010.0 7.2
1413131484423130.020.015.4
14 1291414042110.010.0 4.2
14 1461454021130.010.0 6.2
14 1451424022130.010.014.2
14 2111474022130.010.0 8.2
1413061484422130.010.018.5
1413111424233120.020.0 8.6
14 5381474022130.010.013.2
14 6921464611130.010.0 7.5
1415261414534120.020.0 3.8
1416421424531120.010.012.0
1416391404522130.010.0 9.5
14 4021404041110.010.0 6.2
14  201444212130.010.0 9.2
14  221424213130.020.011.0
24 3961424022330.010.0 7.6
2415251434533320.020.012.3
2413121494223330.020.020.0
24 2141444632320.010.014.1
24 1281424022330.010.016.2
2412981414422330.010.016.8
2413151474223330.020.010.3
2413811464412330.010.013.5
24 5371494011330.010.012.4
24  291494322330.010.014.6
24 5361464012330.010.0 9.6
24 5281424613330.020.013.9
24 4031494034320.020.0 6.6
2415291434514330.020.024.0
24 1261444021330.010.0 7.0
2413161404213330.020.010.2
2416411444611330.010.0 9.3
2416401434533320.020.0 4.0
24 1431484012330.010.016.0
24 1321454022330.010.0 7.2
24 5811454631320.010.012.2
2415301474522330.010.022.9
2415281424521330.010.014.6
24 1251464024330.020.015.4
24  311434323330.020.019.2
24 1301424011330.010.011.4
24 3981414022330.010.010.4
```

TABLE I-V

Male Subjects 50 - 59 Years

```
15 4081505024130.020.0 4.0
15 2181585023130.020.0 7.0
15 6741515041110.010.0 3.5
15 6501575033120.020.014.8
1512861505432120.010.012.6
1516481575542110.010.0 7.2
1516481505523130.020.0 6.2
15 2211515243110.020.0 9.3
1513821555422130.010.020.4
15 4071505032120.010.011.6
1512931535411130.010.0 7.0
15  331515222130.010.016.2
1510981545022130.010.010.2
1518871555022130.010.010.8
15 2191535012130.010.011.2
15 4151525021130.010.0 8.8
15 6341515033120.020.0 7.4
1518351565021130.010.0 7.0
15 6481555023130.020.0 8.0
15 1471585023130.020.0 4.2
25 6321565032320.010.013.4
25 1481505012330.010.0 9.4
2516441595532320.010.0 7.8
25 4091515042310.010.014.8
25 6801515023330.020.015.1
25 4051585022330.010.011.2
25 2161545012330.010.010.8
25 5451555643310.020.0 6.6
25 6721515032320.010.0 6.0
25 6231545022330.010.013.4
25 6461545032320.010.016.8
25 1501525021330.010.0 5.6
25 2171555011330.010.021.0
25 2201575023330.020.011.0
25 4061565022330.010.012.2
25  361505221330.010.0 8.6
25 4131565611330.010.0 7.4
2518831595021330.010.012.1
2512891525422330.010.010.4
```

TABLE I-VI

```
Male Subjects 60 - 74 Years
16 6811606031120.010.0 6.9
1610751650013130.020.0 8.0
1615351606531120.010.0 8.8
1612921616424130.020.010.8
1618281616022130.010.0 9.2
1610741670033120.020.0 6.0
1615361656522130.010.0 9.0
1618721636031120.010.0 9.6
1616761606022130.010.0 7.6
1612941636421130.010.0 7.8
26 2271656024330.020.0 5.8
2618271606013330.020.011.4
2618671706021330.010.0 9.1
2618901746022330.010.0 8.6
2618961676032320.010.0 8.7
26 1211676011330.010.0 7.4
2618781626024330.020.013.7
26 4211606014330.020.0 9.2
2616701696012330.010.010.1
26 2281616012330.010.012.4
2618481676023330.020.012.2
```

TABLE I-VII

Female Subjects 14 - 19 Years

```
1111142151131120.010.0 9.6
1111342151122130.010.013.2
1111752151141110.010.0 5.8
1111832131122130.010.020.3
1111402151153110.020.014.2
1111522151141110.010.012.4
1111532151142110.010.010.0
1117502191031120.010.014.8
1112102131131120.010.015.4
1115492191521130.010.022.9
1111382151131120.010.014.3
1115482191541110.010.012.0
1111362151131120.010.010.8
1111472151122130.010.017.6
1111892151132120.010.017.4
1111852151131120.010.022.3
1111802141131120.010.014.2
1111812141122130.010.013.3
1111552151121130.010.014.9
1111212151132120.010.013.2
1112002141131120.010.015.3
1111722151133120.020.0 8.8
1111312161131120.010.014.4
1111112151133120.020.016.6
1115502191521130.010.0 8.0
1113502191423130.020.012.0
1111042171132120.010.015.0
1111132151133120.020.010.4
1111642151142110.010.020.4
1111432161123130.020.025.2
1111302151143110.020.011.7
1111542151131120.010.0 6.6
1111502151113130.020.013.2
2111122151123330.020.025.0
2111242151122330.010.018.1
2111652151121330.010.012.2
2111572151123330.020.014.1
2111452151123330.020.010.4
2111202151121330.010.022.2
2113602191421330.010.019.0
2113632191431320.010.026.8
2111292171121330.010.030.0
2111272151121330.010.026.4
2111872141122330.010.011.6
2111902151123330.020.029.5
2111252161121330.010.020.3
2112062141121330.010.021.9
2111932141123330.020.013.2
2111092171121330.010.015.8
2111032161123330.020.026.2
```

TABLE I-VII (continued)

```
2111072151123330.020.018.5
2115402191521330.010.012.8
2111172151122330.010.011.6
2111072151133320.020.013.8
2111962151121330.010.016.8
2111942141121330.010.016.0
2111062151121330.010.0 7.6
2115402191533320.020.022.1
2111512161142310.010.012.5
2111582171121330.010.014.0
2111192151123330.020.014.2
2115472191511330.010.016.8
2115452191521330.010.021.6
2115432191533320.020.0 7.0
2113022191423330.020.015.2
2111402161123330.020.020.7
2111842141141310.010.010.2
2111992141122330.010.023.2
2113612191423330.020.028.0
2112092141131320.010.028.4
2112022141121330.010.021.8
2115512181631320.010.014.0
2111742161121330.010.015.4
2111922151132320.010.035.7
```

TABLE I-VIII

```
Female Subjects 20 - 29 Years
1215852232521130.010.017.0
1215112202521130.010.013.0
12 2902262023130.020.014.4
1215042202532120.010.026.0
12 5232222633120.020.011.3
12  922292013130.020.019.4
1213782202413130.020.010.8
1215162242522130.010.011.0
1213392212423130.020.018.6
12 3142202021130.010.021.2
1215832232521130.010.011.4
1215182242523130.020.015.4
1214802202533120.020.017.4
12 6692272011130.010.017.3
1214992222523130.020.0 9.9
1215202222532120.010.016.4
1214922252522130.010.016.0
12 2812292021130.010.017.2
1213422212423130.020.018.4
1212292212421130.010.017.8
1212362212423130.020.023.6
1215032202521130.010.012.8
1215942292043110.020.0 6.8
12 5172222043110.020.010.0
1213722202423130.020.0 7.5
1215812292022130.010.017.2
12  892232042110.010.010.8
1215782232513130.020.014.4
1217492232033120.020.011.0
12 2822212022130.010.017.2
12  942202031120.010.0 9.6
12 6012282631120.010.011.6
1215792292532120.010.010.3
1214102232742110.010.012.2
1217482202033120.020.011.2
1215842202521130.010.020.2
1216122222022130.010.015.6
1215982202023130.020.017.2
1215142202522130.010.0 7.9
12 4892242033120.020.015.0
22 5192292623330.020.016.6
2215082212522330.010.015.5
2214842202531320.010.015.8
2214932262523330.020.012.4
22 5182242011330.010.0 8.3
2215152222521330.010.0 9.4
2212232292431320.010.016.2
2213752202423330.020.013.8
2212272272423330.020.022.2
2213372202031320.010.022.0
```

TABLE I-VIII (continued)

```
22 2022272023330.020.019.2
22 3172202021330.010.012.6
22 4922232023330.020.010.2
22 4962212021330.010.023.2
2214902292533320.020.010.0
22 6112282011330.010.014.6
22 6122262031320.010.020.4
2215132232521330.010.024.8
2213692282021330.010.022.8
22 3562262023330.020.017.8
2213412242433320.020.014.6
22 5992272031320.010.016.2
22 3092262021330.010.027.2
2216132212032320.010.018.6
22 4902242021330.010.011.2
22 6102292023330.020.029.2
2214962222521330.010.015.6
2214872202523330.020.018.0
2212342252421330.010.0 8.5
2212262252421330.010.014.0
22  912232021330.010.032.2
2214822232521330.010.013.8
2215862282531320.010.015.1
22 2922242023330.020.019.7
22 2012212023330.020.013.1
22 2882232012330.010.018.8
22 2832252022330.010.016.3
22 1962262021330.010.011.6
22 1872252011330.010.010.7
22 5982262623330.020.0 8.0
22 4912292023330.020.017.8
2215442202521330.010.014.7
2214952222521330.010.010.6
```

TABLE I-IX

Female Subjects 30 - 39 Years

```
13 3892303031120.010.019.2
1313572303423130.020.011.2
1314782373531120.010.011.2
1313552373422130.010.014.2
13 5842373031120.010.010.2
13 2752303023130.020.0 8.6
13 5312313023130.020.012.0
1315392303512130.010.012.6
13 1852323033120.020.011.4
13 3052303033120.020.0 8.6
13 6142333023130.020.023.2
13 2772313042110.010.013.1
13 1902373032120.010.017.4
1316182333021130.010.024.7
13 3762373012130.010.018.4
13 3832353023130.020.016.4
13 3012303021130.010.011.1
1314792303523130.020.018.1
13 6642343011130.010.013.6
13  492383041110.010.019.4
1316092333021130.010.014.6
13 3202303023130.020.013.5
13 3802313023130.020.018.0
1313512353413130.020.010.4
1313582343431120.010.016.6
1318412313031120.010.012.4
13 3792333041110.010.020.4
13 1932303021130.010.012.8
13 5862343032120.010.015.2
13  662353021130.010.011.2
13  512363022130.010.016.4
1313682313043110.020.023.8
13 5132313632120.010.017.4
1314752303522130.010.012.4
1315542323032120.010.010.3
13 3222303031120.010.013.6
13 2552303031120.010.010.4
1315532393511130.010.014.7
13 6152343643110.020.015.4
13  612303023130.020.013.8
13  552313041110.010.013.8
13  672303013130.020.0 9.2
1318432303622130.010.013.2
1313492323421130.010.030.8
1312722333441110.010.018.8
13 6132363021130.010.024.0
```

TABLE I-IX (continued)

```
23 3862323021330.010.020.0
23 3882313031320.010.013.5
23 1912303021330.010.021.9
2312732323413330.020.011.1
2313482373022330.010.028.6
23 1922313023330.020.026.0
23 2782333022330.010.018.7
23 2522373012330.010.012.1
23 3852363021330.010.018.8
23 3022393032320.010.010.3
23 6852393031320.010.038.2
23 5272303021330.010.013.2
23 3212343021330.010.025.0
23 4842353023330.020.026.9
23 3002323021330.010.026.0
23 2992303023330.020.026.8
2314742383522330.010.020.6
23 5142353021330.010.016.7
23 6632363023330.020.027.8
23 6162393031320.010.022.4
2313442393011330.010.028.0
23 3272383021330.010.013.7
23 3102333031320.010.013.1
23 3922383023330.020.015.6
23 3772353023330.020.016.8
23 4862373023330.020.018.4
23 5122313021330.010.016.2
23 5832393021330.010.021.6
23 6072333021330.010.021.4
23 5152313021330.010.011.1
23 3752353021330.010.016.2
23 3262363011330.010.024.4
23 1942393011330.010.020.3
23 3872353032320.010.013.3
23 6022393011330.010.017.6
23 4612393031320.010.024.1
2315552383041310.010.012.8
2313462383033320.020.011.8
2313522333021330.010.034.8
23  652303021330.010.017.6
23  532303033320.020.010.2
23  592363023330.020.017.8
23  632383021330.010.015.4
2316082323013330.020.017.8
23 6052353023330.020.013.0
23 4812323012330.010.016.5
23 4592353021330.010.012.6
23 5112303022330.010.014.4
23 4552363011330.010.015.8
```

TABLE I-X

Female Subjects 40 - 49 Years

```
1415912484033120.020.016.0
14 5332414651110.010.0 9.2
14 4712404023130.020.0 7.0
14 4752494031120.010.011.6
14 6582404632120.010.025.7
1416312414023130.020.017.0
14 6702474641110.010.016.4
14 5242404631120.010.011.1
14 1532434031120.010.018.0
14 1752414031120.010.024.7
14 1732454031120.010.025.9
14 3422444023130.020.019.2
14 5102424622130.010.014.2
14 4702404032120.010.020.0
14  762474032120.010.013.2
14 5002444041110.010.013.6
14 4642494033120.020.017.6
14 4682424021130.010.018.0
14 3192414021130.010.020.0
14 2682414022130.010.013.3
14 1582474031120.010.024.5
14 6572454023130.020.013.5
14 6602424031120.010.017.7
14 4602444021130.010.012.0
14 4782434013130.020.012.4
1416212454031120.010.025.3
1416322434021130.010.021.1
24  842494041310.010.018.8
24 2642414023330.020.022.1
24  692474031320.010.015.6
24 4772454021330.010.018.0
2418682494011330.010.020.0
2415882484041310.010.023.0
24 6552474611330.010.020.2
24 2672404022330.010.019.2
24 1712464013330.020.031.2
2415902464022330.010.018.2
24  752464013330.020.0 8.2
2413682444031320.010.028.0
24 5922454021330.010.012.8
24 4792404021330.010.026.8
24 2692474012330.010.027.4
24 1572494032320.010.030.0
24 2932444013330.020.024.4
24 1742494023330.020.026.0
2410242404021330.010.027.2
24 4742404032320.010.017.0
24  722444023330.020.017.4
```

TABLE I-X (continued)

```
24  772474023330.020.016.7
24 0522484021330.010.019.8
2416282434023330.020.012.1
2410232434032320.010.016.4
24 1762484021330.010.010.6
2415892464021330.010.024.5
24 3642494022330.010.016.2
2415872464021330.010.026.7
```

TABLE I-XI

Female Subjects 50 - 59 Years

```
15 6292545021130.010.013.8
15  792575023130.020.016.4
1516902515021130.010.012.2
15 3692535033120.020.019.4
1518932505023130.020.016.3
15 2402545021130.010.015.8
15 5952505021130.010.016.8
1516822565021130.010.038.0
15 5772515013130.020.022.6
15 6442505023130.020.013.3
1517152505022130.010.029.8
1519002565032120.010.018.0
15  852505021130.010.018.0
1518732525031120.010.015.5
1516342515533120.020.010.6
1516792575012130.010.017.8
1518462515021130.010.014.7
15 4502545023130.020.011.0
15 2472525021130.010.019.4
15 5782565022130.010.0 9.6
15 5962565013130.020.012.7
15 6222535031120.010.025.5
1518522575021130.010.012.9
15  862505031120.010.012.8
15 6842545021130.010.012.8
1516852505021130.010.013.0
15 3482545031120.010.018.4
25 6242545023330.020.021.9
25 6832575011330.010.028.0
2518982535032320.010.018.6
2516942565031320.010.027.0
2519022575031320.010.024.0
2518542585032320.010.012.2
2512842595413330.020.023.4
2512822505421330.010.023.4
25 1642575031320.010.014.2
25  832525023330.020.013.4
25 3702505023330.020.020.4
25 4482545021330.010.031.6
25 1672555011330.010.032.5
2518532535021330.010.015.7
2512832545421330.010.014.2
25  822525023330.020.020.0
2518202535013330.020.018.4
25 5942555011330.010.017.8
25 6202515041310.010.021.5
2518642535032320.010.027.7
2518502565031320.010.012.8
```

TABLE I-XI (continued)

```
25 3042565021330.010.026.6
25 3732505013330.020.026.4
2516912545021330.010.025.8
2516882585022330.010.017.6
25 6472505031320.010.019.4
```

TABLE I-XII

Female Subjects 60 - 74 Years

```
16 6422616023130.020.022.2
16 0392046033120.020.024.0
1618812616021130.010.028.9
1610622646021130.010.024.2
16 0822616031120.010.015.0
16 0432060022130.010.021.9
1618592640031120.010.018.5
16 2572650013130.020.011.1
1610582666023130.020.018.0
1618772656041110.010.012.9
16 0402646033120.020.018.0
1617122660022130.010.013.5
1610592626021130.010.028.6
16 0202606021130.010.010.6
16 2622620031120.010.020.9
2618612650021330.010.011.7
2616642680021330.010.017.7
20 1832620021330.010.013.0
2618692660021330.010.0 8.4
26  432656021330.010.018.4
2618742606031320.010.024.9
26  422656021330.010.018.0
2610532626031320.010.019.8
2618842696031320.010.016.6
26 3582646021330.010.022.8
2618822616031320.010.011.4
26 1792646023330.020.026.4
2616652650022330.010.017.7
20  402676023330.020.020.0
26 0362600023330.020.023.3
2618712616021330.010.016.0
2610602656043310.020.022.4
2618752620041310.010.018.7
26 4532630011330.010.028.8
```